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Open Architecture, Dual Commercial/Military Use
of Large Displacement Unmanned Undersea Vehicles

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Program Manger for Unmanned Undersea Vehicles (PMS-403)
Naval Sea Systems Command

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Executive Summary

The Naval Sea Systems Command (NAVSEA) Program Manager for Unmanned Undersea Vehicles (UUVs) (PMS 403) requested the National Defense Industrial Association (NDIA) Undersea Warfare Division conduct a study on the potential for a large displacement UUV to be commercially designed for dual use such that it had commercial enterprise viability and also be a platform to test military payloads during periodic fleet battle experiments.

Major issues. **(1) The UUV is an important and versatile transformational element that can bring unique capabilities to the Navy of the future, particularly in pre-emptive and first response. It has the potential to become an essential part in the Navy's FORCEnet concept** in providing real-time information to gain an asymmetric advantage. **(2) Realization of the full potential of the UUV as a truly Autonomous Undersea Vehicle (AUV) in warfare will begin with a transition to a large displacement vehicle**. The capability of small displacement UUVs will greatly limit what UUVs can provide as multi-mission assets and limit their true autonomy. **Larger displacement UUVs must be integrated into new platform designs such that they can be viable organic assets.** Utility as a force multiplier must be evident or the large footprint of a large displacement UUV and its support equipment will not be allocated space in future warship designs. **(3) The expanding commercial market must be leveraged to ensure that new systems can be developed in an affordable manner,** using commercial standards. An expanding commercial market enables companies to provide systems that have military application while at the same time being commercially marketable.

Technical market research on a number of existing UUV programs provided information to assess our business cases from a broad range of designers, manufacturers, missions and users. They ranged from large Defense suppliers to small research companies, Navy and academic research laboratories. **The researched historical programs revealed, many successes and failures**, albeit with limited operational missions and customers. These programs provided insight into the development and analysis of business cases.

Critical success factors and barriers. We found that the **commercial market for AUVs would probably be increasing** in robustness in the next five to ten years; however, competition, particularly foreign, would be keen with more commercial firms entering the marketplace.

Potential UUV Business Cases. The team postulated and analyzed a family of cases. These included: **(1) Traditional Government Procurement, (2) Commercial Off The Shelf (COTS) Vehicle with a Short Term Government Lease, (3) A COTS Vehicle Modified for Navy Use with a Long-Term Lease, and, (4) Commercial-Navy Enterprise Partnership.** The analysis of these cases included Cost, Technical, Schedule, and Programmatic factors. These were further broken down into sub-factors. Costs included development, construction supportability, operation, damage//loss, indemnification and cost risk. Technical factors included Common standards for payload flexibility, vehicle standards, operational requirements, operational security, and technical risk. Schedule factors included time to field the system, operational schedule and vehicle availability, and schedule risk.

Findings

The prospect of the Navy having a large displacement UUV designed and developed by a commercial firm and then made available for Navy use on an "as needed" basis for testing UUV multi-mission concepts has business merit from the Government standpoint only. The commercial market does not currently have the market attractiveness, nor do US commercial firms have enough competitive advantage in a large UUV business model without some Government partnership or guaranteed usage.

There is no clear demand for large UUVs in the private sector in the near term. Small UUVs are more marketable because they provide for current needs and are easier to handle. It is, currently, not clear what commercial advantage a large UUV would offer that would offset the larger business cost. Using a dual commercial-government scenario the current availability of large displacement UUVs that could be used as is or be modified for use by the Navy is limited.

Developing and proving the application of large UUVs in both military and commercial applications is necessary to create a market for these vehicles. Before a large UUV procurement can be pursued, the Navy must prove that it is worth the extra footprint and infrastructure required on the combatant ships of the future. Commercial manufacturers must prove that the additional burden required to operate a large displacement UUV is offset by its added functionality and capability. There is a large amount of anecdotal information suggesting that large UUVs with extended mission capabilities, endurance and autonomy can be a viable and cost effective systems in both the military and commercial marketplaces. However, hard data does not exist to convince commercial manufacturers, the Navy, commercial customers and academic research institutes to invest without engaging in some type of enterprise that shares the cost and risk burden. **The only viable option that would create a win-win scenario appears to be for the Navy to partner with both a commercial firm and a research facility.** In the current market where there is low demand for a large vehicle. Including a research facility (e.g., ARL PSU) would be essential to maximize vehicle utilization. This partnership could be used to develop a large displacement UUV to prove the increased utility and operational effectiveness of a larger vehicle in military, commercial and including research applications. **This enhanced market attractiveness of a large displacement UUV, achieved by developing a strong case for its increased operational effectiveness, could put the partnership at the front of a bow wave of large UUV development that could place it far ahead of the competition.**

Introduction:

The National Defense Industrial Association (NDIA) Undersea Warfare Division was requested by the Naval Sea Systems Command (NAVSEA) Program Manager for Unmanned Undersea Vehicles (UUVs) (PMS 403) to conduct a study on the potential for a large displacement UUV to be designed for dual use such that it had commercial enterprise viability, but also would be constructed to open standards such that the U.S. Navy could use the vehicle to test military payloads during periodic fleet battle experiments. This would enable the Navy to test new concepts for large displacement UUV employment without the need to develop a dedicated test vehicle through the Government acquisition process. The assumption was that the demand for Autonomous Unmanned Vehicles (AUV) for private sector use is increasing and that a commercial venture could be both profitable for the private enterprise, but also compatible with military payloads, and leased by the Navy on a short-term basis for experimentation.

Large UUV Military Utility. The use of unmanned vehicles is one of the important elements of the Department of Defense (DoD) Transformational Programs initiative. The Navy's current research into 21-inch UUVs has proven the concept of autonomous operations, which they are operationally fielding as the Long-Term Mine Reconnaissance System (LMRS) (AN/BLQ-11). With the size of the 21-inch vehicle come inherent physical limitations in both payload and energy storage. A larger vehicle allows for more payload and energy storage for longer endurance. These larger vehicles have a promising future. They can extend the operational capability of surface ships. They can also be a force multiplier for increasing the operational capability of submarines. They can be deployed from the Trident SSGN conversion, submarines with dry deck shelters, be an external payload for submarines using a mother ship concept (e.g., DSRV, ASDS[1]) or be designed into the external structures or modular payload sections of future submarines. These large UUVs can also have significant commercial application, which offers the potential for dual-use capability.

Military - Commercial Synergy. This study explores the feasibility of designing and operating a large displacement (size to be determined) UUV built to standard open architecture specifications similar to those currently being developed by the Navy for the Mission Reconfigurable (MR) UUV[2]. There are many commonalities between the commercial and military uses of UUVs that could benefit from a joint development program. Some of these include propulsion systems, command and control, high energy density power sources, and the potential for underwater recharging to increase mission duration. A reconfigurable payload section would serve to introduce promising technologies to Fleet operators in advance of the formal acquisition program's ability to deliver those capabilities and also provide a vehicle for commercial payloads. The concept that this study explores is to build the UUV for dual use as a commercial vehicle and also as a vehicle to carry military payloads for military employment

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[1] Two Deep Submergence Rescue Vehicles (DSRVs) (Mystic and Avalon) were developed by the US Navy for deep water submarine crew rescue. The Advanced Swimmer Delivery System (ASDS) is the replacement for the aging Navy SEAL swimmer delivery systems.

[2] Lockheed Martin Corporation – Perry Technologies has been awarded the initial contract to develop an Advance Development UUV, which will be the predecessor to a MRUUV program. The MRUUV is a 21-inch diameter based design intended for submarine launch.

experimentation. Operation of the vehicle part of the time with commercial payloads for private sector customers (e.g., telecommunications/petroleum industry) would off-set the cost of vehicle design and fabrication and create a private market upon which industry could capitalize. The remainder of the time, the vehicle would be available at a discounted cost to the Navy to test developmental payloads in Fleet Battle Experiments and NAVSEA's submarine payloads and sensors demonstrations (e.g., the SSGN concept).

Study Scope and Limitations. This study was designed to provide valuable information to our industry partners and the Navy as a basis for them to make informed decisions regarding the tradeoffs required to make such an effort feasible. It can be used as a "jumping off point" by individual companies and the Government to determine if further pursuit of such an endeavor makes good business sense. It provides for an understanding of the critical factors that must be addressed. The study, by design, stops short of providing specific recommendations on how to address those critical factors. Those solutions will develop through proprietary research by individual companies within the competitive marketplace.

Terms of Reference

The NDIA and PMS403 entered into a Terms of Reference (TOR) that defined the scope of the study. The TOR is provided as Appendix A.

Study Members

We solicited study participants from NDIA member companies. The study team was composed of representatives from every major US potential UUV manufacturer. Representatives of the Navy, the Coast Guard, academia and other commercial enterprises, also participated in, or provided information for, the study. These study members and their organizations provided significant in-kind support for this study that was conducted by NDIA at no cost to the Government.

Overall Study Methodology

The study explored the sponsor’s concept by:

1. Identifying the major issues involved
2. Conducting technical market research
3. Identifying historical proofs of concept
4. Identifying critical success factors and barriers
5. Developing families of procurement options to analyze as business cases
6. Developing criteria on which to analyze each business
7. Conducting an analysis of each business case

Identification of Major Issues

The UUV as an Important Transformational Element

> "Naval forces are unique in their contribution to the nation's defense. Versatile naval expeditionary forces are the nation's first responders, relied upon to influence the course of a crisis, control the early phases of hostilities, and set the conditions for decisive resolution. America's ability to protect its homeland, assure our friends and allies, and deter potential adversaries depends on maritime supremacy and credible projection of combat power. The transformation of naval forces is dedicated to greatly expanding the sovereign options available worldwide to the President across the full spectrum of warfare. The result of our transformation will be a Navy -Marine Corps Team providing sustainable, immediately employable U.S. combat power, ready to meet any challenge."[3]

Persistent Intelligence, Surveillance, and Reconnaissance (ISR)

UUVs will play an important part in persistent ISR in the transformed Navy of the future.

> "Combined with joint, and national ISR systems in the Expeditionary Sensor Grid (ESG), naval ISR capabilities will be significantly increased by the next generation of multi-mission maritime aircraft as well as naval Unmanned Aerial Vehicles (UAVs) with mission-reconfigurable advanced sensors; by continued development of Unmanned Ground Vehicles such as the Dragon Runner prototype; and by a family of Unmanned Underwater Vehicles and a program to develop new payloads and sensors that can exploit the large open-ocean interface provided by SSGN. Deployment of UUVs and SOF insertion from VIRGINIA-class submarines and SSGNs will also provide critical close-in ISR capabilities. The Expeditionary Sensor Grid, which will extend from subsurface to space, will provide pervasive, persistent battlespace sensing to create shared awareness throughout the theater and support agile, adaptive battleforce operations."[4]

In the world of Network Centric Warfare, UUVs will be an integral part of the information grid as a part of the Navy's FORCEnet information network initiative not only in providing for force integration but also in gathering and relaying important real-time in-situ data.

> "FORCEnet will provide: …
> … • Integration of all force elements throughout the battlespace , including: satellites, manned aircraft, ships, submarines, UCAVs, USVs[5], UUVs, unattended

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[3] England, Gordon; Navy Transformational Roadmap 2002

[4] Navy Transformational Roadmap 2002, pp. 10

[5] Unmanned Combat Aerial Vehicles (UCAVs), Unmanned Surface Vehicles (USVs)

> space, air, ground and sea sensors and most importantly the warfighters, afloat and ashore.” [6]
> “Major programs that will support FORCEnet, include: …
> …• Real-time Meteorological and Oceanographic Battlespace Characterization for gaining asymmetric advantage by collecting, processing, and exploiting environmental data on-scene in synchronization with the battle forces. This will employ UUVs, UAVs, and USVs, satellite downlink, tactical radar, and high capacity computing capability.”[7]

Transition to a Large Displacement Vehicle

Although technology advances allow for smaller payloads, innovative prime movers, and high energy density power sources, the capabilities of current small displacement UUVs significantly limit their capabilities and endurance. The transition to larger displacement vehicles is a necessary evolution to enable the UUV to satisfy the demands to be placed on unmanned platforms of the future in higher endurance, larger and more capable payloads and advanced autonomy. Larger payload capacity would enhance the multi-mission and mission reconfigurable options available and place fewer limitations on evolutionary design and development.

Integration of Large UUVs into New Platforms

In the US Navy, larger UUVs (21 inch) have been operationally deployed primarily from submarines.[8] The AN/BLQ-11 LMRS is the first US military production UUV in the Fleet[9]. The UUV master plan[10] specifies a number of missions that would be provided in the evolution of the military UUV. The LMRS, with its limited mission, satisfies only the initial phase of the master plan and a new design is required to provide for other plan-specified missions. The development of the Mission Reconfigurable (MR) UUV will provide proof of concept for new UUV capabilities, but the integration of future UUVs into new platforms must break the 21-inch vehicle constraint.

Tethered Remotely Operated Vehicles (ROVs) and small UUVs have been used for some time in a research and oceanographic capacity from US Navy surface vessels. However, there has been little employment of untethered UUVs from surface vessels in support of military operations. With the large emphasis in the use of unmanned assets, UUVs will be considered for inclusion as an organic asset of all new platform developments. Because of the large footprint and support

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[6] Navy Transformational Roadmap 2002, pp. 26

[7] Navy Transformational Roadmap 2002, pp. 27

[8] There are some unmanned submersibles that the Navy has employed from surface vessels for research and development. The Naval Undersea Warfare Center, Naval Oceanographic Office (NAVOCEANO) and the Naval Mine Warfare Command have developed and launched small UUVs from surface platforms for special research, data gathering and mine detection missions.

[9] Northrop-Grumman developed a Near-Term Mine Reconnaissance System (NMRS), under a Navy contract, as a forerunner of the LMRS, but it never became a fleet operational asset. At the writing of this study, there is indication that the Navy may limit the number of LMRS systems purchased and place higher investment in the MRUUV and Large Displacement UUVs

[10] US Navy UUV Master Plan - November 2004.

infrastructure that comes along with them, large displacement UUVs will be part of the design specifications for new platforms only if they provide significant enhancements to the platform missions.

Leveraging UUV Technology in an Expanding Commercial Market

UUV technology in the commercial world has been expanding. Even before September 11, 2001, the value of using unmanned assets for undersea work was gaining momentum. This was fueled by an expanding commercial technology base that both increased the capabilities and reliability of commercial hardware. The use of common standards for microprocessors and the advent of off-the-shelf hardware that could be used for highly technical systems broke the dependence on Government-subsidized UUV systems. The applications of UUVs (particularly in an AUV mode) are increasing. Commercial endeavors are trying to eliminate the costly infrastructure and operational constraints of tethered ROVs. ROVs operating in a deep water environment are constrained by the weight of the tow cable; the time required paying out and retrieving the vehicle, and the requirement for a support craft to maintain station in the operating area during the ROV mission. Successful operation of ROVs is also highly dependent on the weather conditions of the support craft. Additional time on station to complete a job significantly increases the overall cost.

"The next decade will see numbers of AUVs entering commercial operations in five major applications: seabed survey, oceanographic data gathering, pipeline touchdown monitoring, floating production system support operations (the hybrid AUV/ROV), and military applications. In addition, there will be application-specific variants. The initial commercial applications will be in the oil and gas industry - Shell International has estimated that AUVs could result in cost savings to them of over $30 million and increased leverage of over $75 million within five years. Other non-oil applications are emerging. At this stage it is not easy to quantify, financially, the benefits deliverable by AUVs. What we are sure of is that commercial AUVs will bring major benefits in specific applications. Regarding deepwater survey, in the view of Fugro Geoservices[11], "The result will be a reduction in survey time of 50 percent."[12]

"Market research we have carried out over a period of years has led us to conclude that there are commercial prospects for three main groups of AUVs: the survey AUV for gathering high quality survey data in deep water, the pipe laying AUV, and the hybrid AUV for subsea intervention. The requirements for the survey AUV and hybrid AUV have been supported by the findings of both the Shell Gamechanger[13] Program and the 1999 SUT Underwater Robotics Workshop[14], and variations of these two groupings will evolve to suit specific purposes.

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[11] Fugro GeoServices, Inc. was formed in January 1999 from the geophysical services division of John E. Chance and Associates, Inc. and the geoscience division of Fugro-McClelland Marine Geosciences, Inc. The resulting company has over 140 employees based in Houston, Texas and Lafayette, Louisiana, and a fleet of four site-survey vessels.

[12] UnderWater Magazine Article reprint: May/June 2000, "What the Future Holds for ROVs and AUVs", John Westwood, pp 1.

[13] GameChanger manages breakthrough idea generation and technology rejuvenation in Shell International Exploration and Exploration. Shell operates like Venture Capitalists, by reviewing submitted proposals, placing

Survey is the immediate commercial application where the AUV may offer lower costs and higher data quality than using conventional ship-based systems. Despite the considerable amount of technology used on modern survey vessels, it is the ship and survey personnel that dominate the daily operating costs. Use of an AUV could involve fewer people and lower-cost vessels - or, by allowing parallel operations, greatly extend the cost-effectiveness of survey vessels. We believe there are a number of applications for the survey AUV: deepwater survey of both sites and pipeline routes, general hydrographic survey for "parallel" operations from survey vessels, and oceanographic survey/data gathering. In addition, there may be opportunities for AUVs designed to survey very long submarine cable routes, or exclusive economic zones.

To be commercially successful in the longer term the survey AUV must offer low-cost deployment options (air, beach, or small boat), long duration, precise navigation, large data storage, underwater docking for recharge or data upload, and low maintenance requirements." [15]

For the commercial market, the need for low cost deployment implies a need to move towards smaller systems. There are real commercial advantages to a system that is small enough that it can be air-shipped and deployed with standard shipboard equipment. The trend towards smaller systems is further re-enforced by the shrinking of sensors and the increase in energy density of Commercial-Off-the-Shelf (COTS) battery systems. This trend is in direct opposition to the needs of military systems which require larger vehicles.

Technical Market Research

We conducted market research into the potential business cases for a dual-use Large Displacement UUV. To focus the research effort, we conducted dialogue with the study sponsor and established broad guidelines to constrain mission and vehicle requirements for the purpose of this study.

Mission Requirements

The specific mission for the study would be bound by the following mission profile.

1. The mission time frame would be to support a position of a Fleet Battle Experiment, the UUV portion of which would be on the order of 1-2 days. The duration of actual UUV deployments would probably be shorter (< 8 hours).
2. Covert launch and recovery would not be required.
3. The actual launch and recovery mode was not constrained. (e.g., the vehicle could be launched from a support craft or towed to the operating area)
4. Covert vehicle operations would not be required. (i.e., sophisticated noise quieting designs were not necessary)

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educated "bets" on high-potential ideas and monitoring and managing progress of accepted proposals (the GameChangers) http://www.gamechanger.nl/

[14] See http://www.sut.org.uk/htmfoldr/10dOIURA_pub.htm

[15] Westwood, pp 1.

Vehicle Requirements

After the mission requirements were established, we defined the following specific vehicle requirements that we would use as a baseline for discussion and to compare and contrast various postulated system configurations and scenarios.

1. A "large diameter UUV" was defined as greater than 21 inches in diameter.
2. Hotel load requirements were not specified.
3. A specific set of common standards would be provided to adhere to commercial standards. (See the "common standards" discussion under "Analysis of Business Cases" below.)

Historical Concept Review

We performed a search for historical data on UUV programs that could provide insight into the factors that comprise a UUV enterprise for large displacement vehicles. This would yield a sense of the scope of the commercial base that is currently available and to provide facts and lessons learned on which to build our analyses. An excellent overview of the state of AUVs in the commercial marketplace, up to the time of the paper, was provided by Robert L. Wernli of the SPAWAR Systems Center, San Diego in a paper presented at Oceans 2000[16] . The search reviewed over 200 potential programs and focused on those programs that used large displacement vehicles (larger than 21 inches in diameter) and also some smaller vehicle programs that provided data on mutual government-commercial acquisition and cooperation programs. A number of vehicle programs were reviewed in detail. The set of vehicles reviewed in detail is, by no means, exhaustive, but endeavors to illustrate the wide range of vehicles in the marketplace. Details of these programs are provided below and technical references are provided in Appendix B. .

Advanced Swimmer Delivery System (ASDS)

The Advanced Seal Delivery System (ASDS) is a large displacement "manned" undersea vehicle designed and developed under a Navy contract by Northrop-Grumman. It is listed here for comparison purposes with UUVs. ASDS is 65 feet long, with a 60 ton displacement. It is battery-powered, with an electric motor for propulsion. ASDS is equipped with multiple sonars, an inertial navigation system, a GPS satellite navigation receiver, and a robust communications suite. Hydraulically elevated masts provide visual and ESM capability, in addition to communications antennas. ASDS provides greater speed, endurance, and depth capability in comparison to existing swimmer delivery vehicles. The first ASDS reached IOC in July 2003

Advanced Unmanned Search System (AUSS)

The Advanced Unmanned Search System (AUSS) features an underwater vehicle, which is unmanned and untethered, yet not strictly autonomous. Communication with a surface ship is accomplished by means of underwater sound, as employed by a sophisticated digital acoustic

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[16] AUV Commercialization – Who's Leading the Pack?, Robert L. Wernli SPAWAR Systems Center San Diego

link. Operation is analogous to radio-controlled robotic space probes: the vehicle generally proceeds on its own intelligence while transmitting status information and mission data, but it can receive new instructions at any time. AUSS is, in fact, far more versatile than a probe, with such abilities as going to a newly commanded location, hovering at a specified depth and location, executing a complete search pattern, or returning home on command.

ARCS

The ARCS vehicle was developed by ISE Research Ltd as a platform for autonomous vehicle research. Sponsors of this program include the Canadian Hydrographic Service, the Department of National Defence, and ISE Research. Development and testing of the ARCS vehicle was undertaken between 1983 and 1986.

The vehicle has autonomous control, navigation, and guidance capability. With a 20 kWh nickel cadmium battery, it has an endurance of 10 hours and a payload capacity of 300 lbs. If a smaller 10 kWh battery is used, the payload capacity increases to 1400 lbs.

Since 1987, the vehicle has been used for the development and demonstration of autonomous underwater vehicle technologies. This has included development of mission controllers, navigation systems, variable ballast and trimming concepts and advanced power sources. Users of the ARCS vehicle system include the Department of National Defence, John Hopkins Applied Physics Laboratory, Rockwell International and Fuel Cell Technologies. Over 800 dives have been conducted. In 1997, a 100 kWh aluminum oxygen fuel cell was successfully tested on a 35 hour continuous run.

Autonomous Bethnic Explorer (ABE)

The Autonomous Benthic Explorer (*ABE*) was designed and built by Woods Hole Oceanographic Institution with National Science Foundation funding to monitor deep ocean hydrothermal systems. *ABE* can operate to a depth of 6,000 meters and remain on-station for many months.

Autosub

Autosub is a long range, deep diving, autonomous underwater vehicle (AUV). It can carry a wide variety of physical, biological and chemical sensors to provide scientists with the capability to monitor the oceans in ways not possible with conventional research ships. Since 1996, Autosub has completed more than 200 deployments, demonstrating the capability for unescorted missions, routine launch and recovery in Force 6 conditions, sensor or data driven path determination and terrain following. The vehicle has been employed in projects ranging from herring stock assessment in the North Sea to mapping manganese distributions in a sea loch. Autosub has also successfully undertaken missions beneath sea ice in the marginal ice zone of the Weddell Sea.

Autosub measurements can include conductivity, temperature, transmissivity, fluorescence, photo-synthetically active radiation (PAR), current velocities, turbulence, ice draft, and water depth. Sub-bottom acoustic profiling can reveal structures of glacial origin in the seafloor sediments, while a water sampler can collect samples for geochemical and biological analyses. Swath bathymetry and side scan sonar can provide measurements of ice shelf, sea ice and ocean bottom relief at high resolution. Other instruments can also be accommodated on the vehicle.

Bluefin-21

Bluefin Robotics has developed several UUVs with diameters ranging from 9 to 21 inches and depth capabilities to 4500 meters. Bluefin has integrated payloads in their 21 inch UUV. such as a Klein 5000 and Edge Tech Side Scan Sonars, Reson 200 kHz Multibeam systems, Marine Sonics Sidescan for Lockheed Martin, Synthetic Aperture Sonars from QinetiQ, the Navy Costal Systems Station and Thales Underwater Systems, and sonars and hydrophones from MIT. As demonstrated by this long list of payloads, the Bluefin-21 design is modular and can easily accommodate different payloads. Bluefin UUVs have been used to support Fleet Battle Experiments since 2000. In 2004 the Bluefin-21 Mission Package participated in Blue Game off the coast of Norway during May, CJTFEX off the coast of North Carolina in June and RIMPAC during July in Hawaii. Although it is a small company that was recently incorporated in 1997, with more than 50 dedicated UUV engineers Bluefin is one of the larger engineering teams in the industry.

Echo Ranger

Echo ranger is a joint venture effort between Oceaneering, Boeing and Fugro. It has just complete sea trails and is back in commercial service with Fugro scheduled to use it for bottom surveys in late 2004. Echo Ranger has an easily-configurable payload bay. It is based on the OSIRIS vehicle developed by Boeing in the early 1990s. OSIRIS was a modular design and fully autonomous. It has a maximum depth of 10,000 feet. The large displacement platform is 18 feet long and 50 inches in diameter, square with rounded corners. It has a maximum speed of 8 knots and a normal operating speed of 3-6 knots. It has a nominal operating time of 28 hours.

Hugin 3000

The Hugin 3000 commercial AUV is rated for 3000 meters (10,000 ft). It has sensors for multibeam bathymetry & imagery, dual frequency sidescan and a subbottom profiler. It has an Inertial Navigation System, Doppler velocity log, Fiber optic gyro, High & Low Speed Acoustic links, and Digital Global Positioning System (DGPS) & Ultra-High Frequency (UHF) radio in surface mode. The Hugin is powered by an aluminum oxygen fuel cell with ni-cad back up batteries. With the fuel cell power source, the AUV can travel at 4 knots for at least 50 hours with all sensors running. Hugin is 5.3m long and 1m in diameter.

Large Scale Vehicles

Although not developed as UUVs, the Navy has two scale-model unmanned vehicles used for testing concepts for new submarines. They are listed here for comparison purposes to AUVs. The Large Scale Vehicle *Kokanee* (LSV-I) is operated by the Acoustic Research Detachment (ARD) for the Naval Sea Systems Command (SEA 073R). *Kokanee* is a one-quarter scale model of the Seawolf (SSN-21). She is an unmanned, battery-powered, free-running model, 90 feet long, 150 tons, with batteries weighing approximately 25 tons and requiring special, high-powered battery chargers. This large-scale structural model was delivered to Bayview in north Idaho in November 1987 and operated in Lake Pend Oreille for research work.

LSV II *Cutthroat*, a quarter-scale version of the Virginia class (SSN774) attack submarine, will be the world's largest underwater autonomous submarine vehicle. At 111 feet long, the Cutthroat is half the size of a World War II submarine. Cutthroat is about 24 feet longer than LSV I to resemble the hull shape of the Virginia.

Manta Test Vehicle (MTV)

The Manta Test Vehicle (MTV) evolved from the need for a larger payload and energy capacity. NUWC Division Newport designed the vehicle to be a test platform for innovative UUV concepts of the future. It built on the technology developed for the NUWC 21-inch UUV, capitalizing on the use of heavyweight torpedo hull sections grouped together to provide larger capacity payload, energy and propulsion sections. Its futuristic design incorporates a custom fiber-reinforced plastic outer hull.

Maridan 6000

The Maridan 6000 is a 600 meter depth rated AUV. It is manufactured by ATLAS Maridan (formerly ATLAS ApS - acquired by ATLAS ELECTRONIX) of Germany. It has been widely used in Europe for high resolution site surveys including off shore oil and gas, telecommunications cable routes, off shore pipelines and other oceanographic surveys.

Must

The MUST vehicle was developed by Perry Technologies (now part of Lockheed Martin MS2). This vehicle is 54 inches in diameter and of a modular nature such that its volume can be increased by adding 2.5 foot hull segments. The range of vehicle lengths can be varied from 22.5 feet to 35 feet. The vehicle is capable of speeds of 0-8kts and depths up to 2000 feet. The current Launch and Recovery System is limited to low sea states. The vehicle is currently being upgraded to conform to the control scheme and modular architecture of the Advanced Development UUV (ADUUV) along with other modifications to allow testing of various energy storage systems. While not being used for commercial purposes, it could be made available for short or long-term lease or some other arrangement.

Seahorse

Seahorse is a large displacement vehicle designed and developed by the Penn State Applied Research Laboratory under the auspices of NAVOCEANO. Seahorse was chosen as the most available and capable large UUV to demonstrate the concept of deploying large UUVs via an SSGN platform. This concept was tested in early 2003 during the exercise Giant Shadow which provided a proof of concept demonstration using a converted Trident for Special Operations support. During exercise, Giant Shadow, the Seahorse UUV was launched from an actual

Trident missile tube. Further concept testing is scheduled during a follow-on exercise called Silent Hammer scheduled for 2004.

Theseus

Theseus is a multipurpose autonomous underwater vehicle developed by International Submarine Engineering, Ltd. for the Canadian Defence Research Establishment Pacific. The vehicle is undergoing test trials. Operations to 1,000-meter depth extending in range up to 350 kilometers have been demonstrated.

Critical Success Factors and Barriers

Critical success factors and barriers cannot be separated into two distinct discussions. Because the requirements for the commercial marketplace may be different than the Government marketplace, a barrier in one context might be considered a success factor in the other. Our discussion below will provide a narrative of each factor and a description of the pros and cons of in each marketplace.

The Commercial Marketplace

A robust commercial marketplace is essential to recovering development costs and makes an enterprise profitable. It also requires either unique capabilities or high value (i.e., low price) in order to capture and retain sufficient market share. There is an increasing desire for smart UUVs. There are also an increasing number of UUV developers seeking to capture market share. Competition is keen and any company that desires to be viable must be prepared to play in the world marketplace. US Government restrictions on technology transfer provide for a complex, circuitous and lengthy approval process for US companies selling to non-US entities.

Increasing Foreign Commercial Suppliers

Foreign competition is formidable. In years past, US companies could leverage their Government contracts to gain a tremendous technology advantage. Today, the technology gap is much narrower and foreign companies have access to commercially available technology that challenges, and often exceeds, that developed by Government funded programs. Foreign trade laws and the establishment of technology consortia and transnational enterprises have made foreign technology and pricing very competitive in both the military and commercial markets. US export laws on UUV technology give a strong competitive advantage to foreign companies that do not have to operate under these restrictions. This advantage is actively exploited by non-US companies and is especially true in the offshore oil and gas industry which requires international deployment of equipment.

Ease of Introducing New Technology

Technology is becoming easier to develop and cheaper every day. An enterprise that does not have easy technology insertion built into its AUV program is doomed to short-term life. Engineering COTS into the initial design and for easier technology upgrade or insertion is absolutely essential for any viable program. Common architectures and standards, along with a "long view" of the potential technology on the far horizon are necessary to provide for adequate up-front engineering to ensure vehicle legacy. The Government can no longer dictate systems and software that are inconsistent with the commercial world. For example, when the Government dictated that all software be written in the ADA[17] language and "C" became the industry software language standard, private Government suppliers constructed ADA "shells" around "C" software to meet the Government specification. Government's attempt to drive the standard in order to amortize their investment in the development of ADA ended up costing them more in the long run. Added non-recurring engineering costs and possibly having to build a completely new vehicle mainframe to accommodate new technology may greatly increase program cost when compared to smart up-front engineering design.

Guaranteed Usage

A guaranteed usage rate greatly enhances the business model. It ensures a certain amount of guaranteed income which, in turn, makes convincing investors and board members easier. Maximizing vehicle usage may be the single most important factor in ensuring the profitability of the business model.

Profitability

Although there is anecdotal information claiming a large, booming commercial market for AUVs around the world, the market is fiercely competitive. The advent of economically available technology combined with cheaper foreign workforce cost, lower export restrictions, and the use of foreign consortia in UUV development have placed US companies at a severe disadvantage. Even with the best-sharpened financial pencils, US companies have an extremely difficult time in being price-competitive.

Historical Program Success

There have been many attempts to field a commercially viable UUV with both commercial and military concurrent application. Lockheed Martin (e.g., with MUST) and Boeing (e.g., with OSIRIS) have both developed UUVs for commercial application. Neither project has panned out. With a lack of prior success it takes a much more compelling argument to get investors and corporate decision makers to buy into any new dual-use vehicles. However, by developing the vehicles Boeing and Lockheed Martin appear to have maintained their competitiveness and may have helped them win future Navy UUV development contracts as a result of thes early development efforts.

Several small enterprises (e.g., Bluefin Robotics, C&C Technologies) have built or used commercial off the shelf technology and had some success in a limited mission environment. C&C's Hugin 3000 UUV has successfully performed many commercial mapping projects for

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[17] The ADA software language was conceived by RADM Grace Hopper, the US Navy's first IT guru. In an attempt to standardize software within the Navy, ADA was dictated, by directive, as the required software language for all Navy software systems.

individual clients around the world. C&C's UUV has mapped a total distance of 35,000 kilometers (19,000 nautical miles), which equates to 5,000 hours or 208 (24-hour) days traversing the ocean bottom collecting data and this does not include the Hugin 1000 accomplishments for the RNoN. Even though its mission environment may be considered limited, the technical success of the Hugin UUV program is significant. Bluefin Robotics has been very successful in providing COTS vehicles for Fleet experiments, albeit with vehicles of 21 inches or less. Their operation is lean and cost effective and has had significant success in using a COTS vehicle for multi-mission use. The Hugin vehicle used by C&C is one meter in diameter and better addresses the issues associated with operation of a large displacement vehicle. The nascent Echo Ranger AUV developed by a consortium of Boeing, Oceaneering and Fugro shows how creative strategic business alliances can help enhance the business model.

Mission Compatibility

Commercial endeavors will reap more benefits from the use of UUVs in a deep water environment. In shallow water, tethered vehicles can be more easily deployed with small cable scopes and human diving operations are a viable alternative. The US Navy, however, is pursuing UUV systems that will provide the advantages of lower risk and persistent presence in a shallow water environment. Although there are some concurrent scenarios for both environments, there are significant differences in design criteria. This works in the Government's favor since a vehicle designed for hull integrity in deep water environment will be adequate in shallow water. On the other hand, unless commercial developers can attract clients with deep water needs, the additional development cost for a deep water vehicle will decrease profit margins. Also, for many commercial shallow water jobs, the cost of human diving operations may become more cost effective when compared to a sophisticated, large UUV.

Establishing Business Cases

Since the viability of such a dual commercial-military use depends on profit for the commercial sector and meeting a budget on the Government side, the study team postulated a family of potential business cases that would cover the range of potential options. This study does not intend to prioritize or make specific recommendations of one case over another, but merely presents findings on each business case to aid the study sponsor in deciding which business case is best suited for the proposed dual-use effort. The business is presented below without any specific order of preference.

Traditional Navy Procurement

In this case the Navy would use traditional acquisition procedures to develop an operational need, program analyses (e.g., Analysis of Alternatives), specifications and a Request for Proposals to solicit designs for a vehicle. This would be a normal competitive procurement using a spiral or evolutionary development process which fields a basic vehicle that would be conducive to technology upgrade insertions. This is similar to the current MRUUV procurement effort. It would entail all the normal DoD 5000 Series procurement rules and Milestone Decision Authority approvals throughout.

COTS Vehicle – Navy Short-Term Lease

In the COTS Vehicle-Navy Short-term Lease case, the vehicle used would be commercially designed and built to common standards (either as a new design, or as an existing Commercial-Off-The-Shelf (COTS) vehicle or with minor modifications to an existing vehicle). Depending on the degree to which military payloads are built to common standards, a COTS vehicle would be compatible for military payloads and operational requirements without the need for major modifications. The design would be driven by commercial needs and the Navy would need to accept a commercial design and lease the vehicle for short periods of time concurrent with specific exercises.

COTS Vehicle – Navy Mod and Long-Term Lease

In this case, the vehicle used would be commercially designed and built to common standards (either as a new design, or as an existing COTS vehicle). It may require significant modifications to make it compatible with the military payloads and operational requirements and would be leased by the Navy for an extended period (1-2 years). The Navy would pay for modifications to meet any unique Government requirements and would return the vehicle to the commercial entity at the end of the lease period. This case is similar to the Navy's HSV-X1 and HSV-X2[18] lease plans, but on a smaller scale.

Commercial-Navy Enterprise

There is a significant element of risk associated with such a dual-use endeavor. So this case provides for a Navy/Commercial Joint development where each shares both the risk and the payoff. The vehicle is built to common standards so that it is compatible with requirements for battle experiments. The vehicle design would also be compatible with commercial applications. This type of procurement option is innovative but may not fit within the current constraints of the Federal Acquisition Regulations. However, it may be the only viable option to procure needed equipment considering limited Defense procurement funds expected in the foreseeable future. A specific concern is: how can the DoD enter into a partnership with a commercial firm that may return a profit for the commercial entity *and* the Government? A Public-Private Partnership would be defined as a contractual agreement between the Government and a for-profit corporation. Through such an agreement, assets of the Government and the private entity would be shared in delivering the end product or service. To be politically palatable, the bottom line must be that the end result is for the good of the public. Both parties share in both the rewards and risks. An excellent source of information on public-private enterprises is the National Council for Public-Private Partnerships[19]. "Over the centuries, but particularly during the last two decades, combinations of public and private resources have been utilized to build water/wastewater systems, education services and facilities, transportation terminals, public safety systems, and many more projects. And efficient business practices of the private sector are increasingly used in operation of a variety of public services."[20]

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[18] The U.S. Navy has entered into lease agreements for an experimental littoral combat ship experimentation platforms called the "Joint Venture" designated HSV-X1 and the "Swift" HSV-X2,. See http://www.foxxaero.homestead.com/indrad_049.html for more details.

[19] http://www.ncppp.org/

[20] *PPPs-American Style* - PFI Journal 39, October 2002

"The current situation with governmental budgets is another major driving force. While far from unique to the United States, there is now an acute public sensitivity about the limitations of government financial resources. Massive surpluses of a few years ago at the state and federal level have disappeared, while there is a growing awareness that many of the long-term needs for infrastructure maintenance and development have been ignored for too long. As public demands for services and facilities continue to grow, and the treasuries at all levels of government are sorely tested, partnerships are often the most viable answer."[21]

Although a case study specific to the DoD is not readily available, there is enough activity on public-private partnerships in other departments at the Federal level that many applicable lessons learned can be gained from those efforts.

Analysis of Business Cases

In the analysis of Business Cases, we formulated a list of business attributes and associated factors. The major areas of evaluation were:

- Cost
- Technical
- Schedule
- Programmatic

Cost

Cost is the predominant driving factor in every business case since a positive return on investment is required. These costs and returns can be either direct or indirect. For example, there can be net loss in the development of a vehicle for Navy use. However, if the business model shows that loss can be overcome in a robust commercial application, or commercial spin-offs of the Government development, the net return on the entire business model can be positive and justify some loses within the overall business scheme.

Costs are broken down further into contributing factors.

- Development Cost
- Construction Cost
- Supportability Cost
- Operating Cost
- Indemnification
- Damage/Loss
- Cost Risk

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[21] *PPPs American Style*

Costs are either recurring or non-recurring. An example of recurring cost would be periodic battery replacement. An example of a non-recurring cost would be the cost of design that lasts the life of the vehicle.

Development Costs

Development costs are primarily non-recurring costs incurred in new vehicle designs and construction and testing of developmental hardware including software models and simulations. In a spiral or evolutionary development, some development costs would be recurring for the added capabilities to be introduced as subsequent modifications to existing vehicle design.

Construction Costs

Construction costs are the non-recurring costs of building a full up vehicle that is based on a developmental design. The design can be in the form of an Engineering Development Model (EDM) that is close enough to the final production vehicle that it can be used in the final vehicle fleet. Construction cost also includes the cost of building the initial fleet of vehicles. A factor that affects Construction Cost is the amount of non-developmental or COTS items in the final design. Another important factor is the number of vehicles constructed, since this will determine the total cost for the fleet of vehicles.

Supportability Cost

Supportability Cost includes those items required to keep the fleet of vehicles in operation over its life cycle. It includes spare parts, non-recurring engineering, maintenance and disposal. It may also include the investment in support infrastructure including shore support facilities and launch and recovery vessels. Supportability costs may become higher than the actual vehicle costs depending on the method of launch and recovery chosen.

Operating Cost

Operating Cost is the cost of operating of the vehicles independent of supportability. It includes vehicle consumables, operating support equipment usage and consumables and recurring technical costs such as providing on-site operators, routine maintenance teams and technical consultants.

Indemnification

Indemnification is insurance on the potential for liability for things such as inability to meet schedules, personal injury, environmental damage or mechanical damage from the vehicle to other equipment, etc. Indemnification costs can be very high. If insurance is purchase, premiums can be high. If a company self insures the program, the risk of a judgment against the company will have to be part of the cost equation. A certain degree of indemnity is necessary to ensure a profitable venture.[22]

Loss/Damage

Although Loss/Damage could be covered under indemnification, it is treated separately to include those costs that a manufacturer or the Navy would likely incur to replace, recover, or

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[22] For further explanations of maritime law see *Recent Developments in Maritime Law*, Office of Charles M. Davis, http://www.davismarine.com/davis1500.php?PHPSESSID=72d2a9ca93b7198ce5ed1067e1277bd2

repair a lost or damaged vehicle or vehicle system as opposed to insurance to cover damage incurred to some external entity.[23]

Cost Risk

Cost risk is a measure of the probability that the program can achieve cost objectives. It is a complex factor that includes a multitude of factors for the vehicle, vehicle support and corporate infrastructure. These include vehicle proposal development, design, development, construction, marketing, marketability, system legacy and the ability to turn a profit at the bottom line.

Technical

Technical factors include those items required to meet the mission specification and how they affect the ability to use the development technology for other applications. The ability to re-use designed or constructed hardware or already developed software in other applications will be dominant factors in the ability to amortize cost and successfully market in other related areas.

Technical factors were broken down into the following:

- Common Standards for Payload Flexibility
- Vehicles Standards
- Operational Requirements
- Operational Security
- Technical Risk

Common Standards

The unique requirements of the Government had historically driven hardware specifications to unique designs. The large Defense budgets of the Cold War Era that made this possible. The Government could afford to pay for unique designs that had little commercial application or could choose to limit the use of those unique designs due to security concerns. Due to fiscal constraints and the fact that lower post-Cold War spending has decreased the number of competitive bidders in the Government marketplace, the Navy is moving towards common standards and architectures. This will greatly aid the application of Government projects development to commercial projects and widen the field of potential hardware suppliers for Government applications. The Naval Undersea Warfare Center (NUWC) is developing a set of common standards for UUVs. These standards endeavor to create a Government specification that allows a greater use of COTS equipment and also allows Government program offices and technical authorities to provide design guidance that will better ensures the end-item performance by capitalizing on the historical experience of commercial designs. Standards are grouped in the following categories.

- Data Formats and Data Storage Media
- Control Architecture
- CPU Backbone
- Connectors

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[23] Charles M. Davis

- Communications
- Power Distribution

Payload Flexibility/Standards

Many of the standards initiatives will facilitate flexibility in payloads and allow the development of multi-mission scenarios for the vehicle. The standards specified will determine to what extent specific designs or common standards will be used. The use of common standards will enable the better use of commercial or non-developmental items. However, this may constrain the operational capabilities of the designs if some payloads do not have commercial counterparts. Payload flexibility is based on factors such as:

- Physical interfaces – that includes physical payload mountings and connectors, and heat transfer mechanisms.
- Electrical Interfaces – that includes power requirements (voltages, AC frequency or Direct Current).
- Size, Weight and Moment
- Modularity - the ability to exchange payloads as a "black box module" that conforms to certain weight, size and physical and electrical interface standards.

Vehicle Standards

Common vehicle standards have less of effect on the ability to field a dual commercial-Government use vehicle so long as payload bay physical size and weight and hotel requirements are adequate for Government payloads. The standards to which the vehicle is designed will determine the capacity of vehicle to perform operational missions. These will be based on hotel load power requirements, weight and moment considerations, stealth, endurance and physical space for payloads.

Operational Requirements

The operational requirements for the vehicle are important in determining basic vehicle design and the ability of the vehicle to meet multiple mission requirements. These requirements may range from mutually exclusive, but compatible, items (such as stealth required for a military mission that will work for a non-stealth commercial mission) or exclusive and non-compatible items such as a special purpose classified communications need for a non-payload communications system). However, a more restrictive design will drive up the cost of a non-restrictive mission design (e.g., a vehicle designed for deep water used in a commercial mission in shallow water)

Operational Security

Although foreign export controls are a normal requirement for all foreign marketing, conformance to specific operational security restrictions would make foreign marketing problematic and require the additional review by the Navy International Programs Office. The optimum configuration for a commercial venture would be to have no classified hardware outside the payload bay and allow software and data outside the payload bay to be easily certified as unclassified after use in a Government application.

Technical Risk

Technical risk is the probability that the system can be delivered as technically advertised. With proven, legacy technology technical risk may be low. High technical payoff can be achieved using COTS or leading edge technology. Although current commercial products normally have high reliability there is less risk associated in the failure of a commercial product operating on dry land as opposed to an autonomous vehicle operating at sea. A keen assessment of the potential risk of achieving advertised technical performance must be made to ensure meeting performance objectives when working with leading edge technology.

Schedule

The factors in scheduling include the time required to develop a new vehicle or modify an existing vehicle to meet the standards required for the Navy's mission. It also includes the availability of a vehicle that is used for both commercial and Navy applications. The schedule factors include:

- Time to Field System
- Operational Schedule and Vehicle Availability
- Schedule Risk

Time to Field System

The time to field the system is the time from identification of the requirement to initial operational capability of the system. It is an important factor both for the Navy and the commercial supplier in that there is little or no return on investment during this time frame. The Navy will have a specific operational schedule to meet and the commercial supplier would benefit if he could get the item to the commercial market faster.

Operational Schedule and Vehicle Availability

The amount of time required for missions, the schedules of missions, the flexibility of mission schedules, vehicle turn-around time, and reliability will determine the amount of vehicle operational time available and thus the number of vehicles required to satisfy the usage required to make it cost effective as an enterprise. A guarantee of vehicle use by the Government would enhance the business model. The commercial company would have to assess the commercial schedule and determine the turn around time for conversion of the vehicle from a commercial configuration to a unique Navy mission configuration and then back again in order to determine the maximum number of operational days available per year.

Schedule Risk

The longer the development schedule, the more time is expended before reaching the profitable time in the system's life. Part of the development time may be outside-funded in some methods of procurement while in others it will need to be borne totally on company funds. In any case, missing the schedule results in higher overall costs and missed operational missions. Schedule risk includes factors such as weather for at-sea testing, the predicted delivery of new technology and delivery of critical items from subcontracted suppliers.

Programmatic

Program requirements include any peripheral development costs such as inspection, quality assurance, reporting, oversight and documentation. These program considerations add considerably to development, construction and operating costs.

- Ease of Development and Construction
- Ease of Operation Contracting
- Programmatic Risk

Ease of Development and Construction

The types of contract vehicles used will depend on the amount of risk involved in development and the amount of oversight required. Easing these requirements will reduce total program costs. Government contracting vehicles, by law, have significant oversight requirements. Recent streamlining of the acquisition system has eased some of the contracting burdens. However, Government contracting always comes with significant costly "baggage". In addition to the cost of the awarded contract, the need for Government inspectors and managers that include the Defense Contract Audit Agency (DCAA), Defense Contract Management Agency (DCMA), and Program Managers add to the total cost of procurement. On the private side, additional personnel are required to provide for internal audits and surveillance to manage those things audited by Government agencies. Publicly traded companies also have significant oversight and scrutiny by stockholders that may require a more compelling case before capital investments are made.

Ease of Operation Contracting

The methods used to contract for vehicle use after development and construction will determine the cost and cost risks in the deployment of the system.

Programmatic Risk

Programmatic risk is the measure of the probability that the program of record can be executed as conceived. It considers the ability to achieve the specifications for meeting Cost, Technical Requirements and Delivery Schedule.

Analysis of Specific Business Cases

Traditional Navy Procurement

A Traditional Navy Procurement, for our analysis, is considered to be a Cost Plus Award Fee (CPAF) contract. The CPAF contract is type of cost-reimbursement contract. The fee consists of a base amount (which may be zero) that does not vary with performance and an award amount. The award amount paid varies according to the government's judgmental evaluation of the contractor's performance in such areas as quality, timeliness, ingenuity, and cost-effective management. [24] The premise is that the contractor is incentivized to perform as directed in the contract. Most Government contracts are now "performance-based". They provide a specific set

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[24] See Federal Acquisition Regulation (FAR) 16.305 and 16.404-2

of standards in a "Statement of Objectives" and a "Performance Work Statement" that specifies performance assessment criteria which the Government will use to determine the amount of a pre-contract-determined award fee pool to be awarded to the contractor at specified contract milestones. For a hardware contract, the criteria lie in the primary specification, the delivery schedule, and the actual reimbursable cost.

Cost

In the traditional procurement, most of the burden of risk lies with the Government. The Government's track record at specifying exactly what it wants in a hardware contract has not been that good. At the time of initial hardware contract award for the Engineering and Manufacturing Development (EMD) phase of acquisition at Milestone B, there tend to be many unknowns. Often during development of the Engineering Development Model (EDM) changes are identified that are beyond the scope of the original contract. If the Government agrees that the changes are necessary, and not already included in the contract, they modify the contract to provide more funding. If the Government does not agree and considers that the needed changes are within the original contract, the result is often litigation, which cost both the Government and the contractor more money. The new paradigm of "spiral" or "evolutionary" development allows improvements (that had been historically attained by "performance creep" and contract growth) to be built into the contract as a phased development. Cost for the traditional Navy procurement heavily favors the contractor and puts most of the cost and risk burden on the Government. The contractor can potentially realize high profit spin-offs into assuming that the Government technical specifications are consistent with commercial market needs and standards. If the commercial standards and Government specifications are consistent, this will prevent costly additional non-recurring costs and will also make the Government contract-specified vehicle attractive in the commercial marketplace.

Technical

In a traditional procurement, the Government can get exactly what is wants. Specifying commercial technical standards will not only make the procurement less costly, but will facilitate system upgrades.

Schedule

The Government process of establishing specifications, writing FAR-compliant contracts and taking a contract through the approval chain makes the schedule process long and drawn out. The advent of simplified acquisition processes has eased this somewhat, however, the scheduling process for the traditional Government procurement is much longer than any other procurement method. Contractor schedule slips can be minimized so long as the Government provides realistic specifications and delivery dates. Even with "cost plus award fee" contracts, hardware primes, to remain competitive, will match their proposed schedules to what the Government specifies in a solicitation, rather than what they think is realistic. Contractors often bet on the Government's traditional penchant for technical changes which will then justify schedule slips to meet the added Government requirements..

Programmatic

The Government programmatic system will always be more burdensome. Since program requirements are driven by statute (e.g., FAR, Clinger-Cohen Act, etc.), the volume of required programmatic documentation and processes far exceed those required in the commercial world.

Example Programs

Since this is the most common contracting vehicle for hardware development, there are many examples. Recent examples include the development of the Near-term and Long-term Mine Reconnaissance Systems development (NMRS (Northrop-Grumman) and LMRS (Boeing) respectively) and the ongoing Advanced Development (AD) and Mission Reconfigurable (MR) UUV programs that will test the viability of multi-mission UUV capability.

Commercial Development – Navy Short-Term Lease

Cost

The cost of design and development is borne totally by the commercial developer. While this cost can be recovered based on the lease terms, cost recovery, and bottom line profitability, depends upon a certain level of vehicle use over the life of the system. A maximum number of vehicle operational days can be estimated. However, there are many unknowns such as vehicle reliability and corrective maintenance, periodic maintenance, turnaround time between engagements, launch and recovery time and transit time to and from operational areas. All this will limit the maximum number of available vehicle days per year. After a prediction of the percentage of utilization by customers, a lease cost required for profitability can be determined. For the Government, the short term lease is the best cost option for a one-of-a-kind developmental vehicle. However, the Government has to conform to the constraints of an off-the-shelf vehicle and to minimize conversion costs, which could, in turn, limit mission effectiveness.

Technical

In building a vehicle without Government intervention, the commercial developer would be unconstrained on the technical specifications (and burdensome government specifications) and be able to design the vehicle for the optimum standards for the overall marketing of the vehicle. The Government would be constrained to the technical standards of the commercially-developed vehicle. Moving Government systems to common architectures and commercial standards would ease the interface issues.

Schedule

Assuming that the short-term lease uses an available vehicle, this method should field a vehicle in the shortest time frame. Schedule impact can occur if there are problems with physical or electrical interfaces that require either vehicle or payload modification. It is incumbent on the Government to ensure that their payloads and hotel requirements are properly supported by the vehicle. Government research and review of proposed suppliers requires some schedule time, but much less than with traditional hardware procurement. As stated in the cost discussion above, the government would have to guarantee the use of a certain number of operational days to ensure that a vehicle was available when required. Yielding the maximum number of vehicle operational days in both the Government and commercial markets requires careful scheduling.

In the profitability equation, a maximum probable number of operational days would have to be predicted based on the perceived ability to optimally sequence events and minimize turnaround time. As an example, Southwest Airlines maximizes aircraft utilization. Their aircraft turnaround time between flights is less than half the industry average. This allows them to operate at the same schedule rate as their competitors with less that 2/3 the number of aircraft in their fleet[25]. Obviously, Southwest has known and standard "payloads", but the example of how turn-around time and scheduling are key to profitability applies to any short-term leasing model. Schedule risk is very high in the absence of any long-term schedule guarantees

Programmatic

Short-term leasing is the least cumbersome of any of the procurement options. Individual contract funding levels are relatively low allowing program managers more authority and ability to make contract decisions and funding authorizations.

Example Programs

C & C Technologies uses a Hugin 3000 vehicle which has provided commercial UUV services for short-term projects, primarily for the oil industry, since 2001. As of July 2004, the Hugin 3000 UUV has performed sixty-five commercial mapping projects for thirty-two individual clients totaling a distance of 35,000 kilometers (19,000 nautical miles). These projects, ranging in duration from several hours to several weeks, were performed at a variety of locations within North America, South America, West Africa, and Europe. Echo Ranger has just been placed back in service, but promises to provide an easily configurable vehicle. Bluefin Robotics UUVs have been used to support Fleet Battle Experiments. The cost of these programs all hinge on a guaranteed Navy usage rate and the ability to flex operational schedules to maximize utilization in both commercial and Navy applications.

COTS Vehicle – Navy Mod and Long-Term Lease

Cost

The cost model for this type procurement is similar to the short-term lease option above. However, the cost to the Government is higher since the Government is obligated to fund any modifications to the vehicle and vehicle systems. Also, the Government must invest in a long term lease to amortize the modification costs. The cost risk is borne by the Government and it is incumbent on them to maximize the vehicle utilization during the lease period. The cost of operation infrastructure for either manning the support systems themselves or contracting the operation out is borne by the Government. If the vehicle can be used for multiple service testing (as the HSV-X1 was used in alternating operation between the Army and the Navy) the business model becomes even more attractive since utilization can be maximized.

Technical

The Government can avoid technical problems by ensuring that vehicle modifications provide for an end product that satisfies all the expected payloads and operational environments during

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[25] Study Questions for Southwest Airlines, 1998, University of Utah. http://www.business.utah.edu/~mgtwh/southwes.htm

the lease periods. The Government also needs to ensure that the baseline vehicle and support systems satisfy the minimum standards to supportability.

Schedule

During the term of the lease, the Government has the maximum flexibility in scheduling. Scheduling risk is minimized since the Navy "owns" the vehicle. However, the prescribed uses must be compressed into a shorter time frame to ensure the best utilization during the lease period.. The HSV-X1 and HSV-X2 were able to be made available for real world Iraq support operations due to the flexibility of their long-term lease options.

Programmatic

Programmatic issues are more complicated with the short-term lease since non-recurring engineering, design, development and hardware construction will be required for the non-standard systems which are added to the baseline vehicle and vehicle systems.

Example Programs

The HSV-X1 and X2 programs are the best examples for of this type of business case. Each was a long-term lease program with a fixed completion date. The Navy sank a significant cost into the vehicle at lease inception that was unrecoverable at completion. The Navy determined that these modification costs, when combined with the lease cost, were acceptable to satisfy program goals over the lease term. Using the vessels during the Iraq War, was not anticipated in the initial business model, but proved to make the vessels even more cost effective and provided invaluable real world data. Although there have been no long-term leases tried for the C&C's Hugin 3000 or Echo Ranger AUVs, it is possible that long-term lease arrangements could be achieved with these companies.

Commercial-Navy Enterprise

This is a potential win-win business case. Each of the cases favors either the Government or the private sector participant. However, this case requires an exceptional degree of cooperation in order to succeed. It also requires an extra effort in "homework" on US statues and, perhaps, regulation changes, but there are many recent case histories in the Federal Government that can be used to glean lessons.

Cost

Cost, in this case, is negotiable. Each party to the enterprise has things that they can place on the table in order to reduce cost or increase profitability. These negotiable items need not, be monetary in nature and can be items provided "in-kind", in lieu of cash. The success of the joint enterprise requires innovative approaches to the funding and profit profiles. For example, the private concern might provide underutilized services or facilities from another business segment at no cost if they would otherwise go unused. Private sector personnel by working extra hours can earn "stock" in the enterprise that would reap a return based upon the success of the enterprise. The Government side is limited on what it can provide, since compensation of personnel is covered by strict laws. However, the Government could provide the use of "in-kind" resources (such as underutilized facilities) to the private concern.

Technical

There will be tradeoffs in technical specifications. However, if both parties work toward common architectures and specifications, technical specifications, the vehicle should be compatible for both Government and commercial uses.

Schedule

The schedule will be driven by the need to get the end product to market as soon as possible. Shortening the schedule minimizes development costs and gets the enterprise providing return on investment (ROI) as soon as possible. Since both partners are driven by a need to maximize ROI, they will each find ways to remove impediments that stand in the way of maximizing returns.

Programmatic

This Commercial-Navy Enterprise case presents a new programmatic paradigm. Even though there have been some case studies done in the private sector, the partners will continuously be looking at new ways of building a system in a complete partnership. The Integrated Process Team (IPT) concept can be used to some extent, but the partners must develop a trusting rather than an adversarial relationship.. There has been a long history of public-private partnerships at state government levels and these cases can be used as a reference for success stories to emulate. The National Council of Public-Private Partnerships[26] is an excellent reference for these types of programs.

Example programs

Although there are no direct examples of Government-Private enterprise programs in the Department of Defense (DoD), there are examples of public-private partnerships between Defense entities and academia and many examples of pubic-private partnerships outside of DoD. The closest example in the UUV world would be the Seahorse UUV program. Although academia e.g., PSU ARL has much more flexibility in this area, there are many lessons learned from this program that prove how cost sharing can yield quick and useful results. Using an existing vehicle ARL was able to provide a short-term solution to prove a concept. Both Government and ARL invested in the project with good success. The Government got their proof of concept demonstrated for Giant Shadow and ARL now has a vehicle hull flexible enough for many different payloads and missions. For a commercial partner, the Seahorse provides a UUV that can compete in the marketplace as an easily reconfigurable test platform for UUV concepts. Perhaps private industry, cooperating with both academia and Government can develop an innovative program paradigm where all three parties can win while developing a large displacement test vehicle that has both commercial, research and Government applications.

Summary

The prospect of the Navy having a large displacement UUV designed and developed by a commercial firm and then made available for Navy use on an "as needed" basis for testing UUV multi-mission concepts has business merit from the Government standpoint only. The commercial market does not currently have the market attractiveness, nor do US commercial

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[26] http://www.ncppp.org/

firms have enough competitive advantage to be able to support a viable large displacement UUV business model. A long-term lease option or guarantee for a significant number of days of Navy usage over a number of years would enhance the model.

There is no clear demand for large UUVs in the private sector in the near term. Small UUVs (21 inches diameter and smaller) are more marketable because they not only provide for the missions currently needed, but are also easier and less costly to handle. It is, currently, not clear what advantages a large displacement UUV would offer in commercial applications. A significant risk would be taken if a commercial firm were to design and develop a large UUV. The current availability of large displacement UUVs that could be used as is or be modified for use by the Navy using a dual commercial-government long-term use scenario is limited. Systems that have some merit are the Hugin 3000, Lockheed- Martin's MUST, and the Oceaneering-Boeing-Fugro Echo Ranger.

Developing and proving the application of large UUVs in both military and commercial applications is necessary to create a market for these larger vehicles. Before a large UUV procurement can be pursued, the Navy must prove that a large displacement UUV is worth the extra footprint and infrastructure required on combatant ships of the future. Commercial manufacturers must prove, and convince their stockholders and potential customers, that the additional burden required to operate a large displacement UUV is offset by its added functionality and capability. No commercial firm or research facility, in the current economic environment, can make the large investment and accept the large development risk alone. The Navy cannot afford to engage in an expensive traditional procurement until the utility of a large displacement UUV is proven in military applications. There is a large amount of anecdotal information that large UUVs with extended mission capabilities, endurance and autonomy can be viable and cost effective systems in both the military and commercial marketplaces. However, the hard data does not exist to convince commercial manufacturers, the Navy, commercial customers and academic research institutes to invest without engaging in some type of enterprise that shares the cost and risk burden. The only viable option that appears to create a win-win scenario appears to be for the Navy to partner with both a commercial firm and a research facility. The ARL-PSU Seahorse Program is an example. However, building a partnership based on a commercial UUV like C&C's Hugin 3000 or the Echo Ranger programs, for example, might also work. In the current market there is low demand for a large vehicle. So including a research facility (e.g., ARL-PSU) would be essential to maximize vehicle utilization. This partnership could be used to a large displacement UUV to prove the increased utility and operational effectiveness of a larger vehicle in military, commercial and research applications. This enhanced market attractiveness of the large displacement UUV, achieved by developing a strong, proven case for its increased operational effectiveness, could put the partnership at the front of a bow wave of large UUV development and could place it far ahead of the competition.

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Appendix A - Terms of Reference

Open Architecture, Dual Commercial/Military Use of Large Displacement Unmanned Undersea Vehicles

A Study by the
National Defense Industrial Association (NDIA)
Undersea Warfare Division
C4I and Undersea Vehicles Committees
for
CAPT John D. Lambert, USN,
Program Manager
Unmanned Undersea Vehicles (PMS403)
Naval Sea Systems Command

BACKGROUND

The use of unmanned vehicles is one of the important elements of the Department of Defense Transitional Programs initiative. The Navy's current research in 21-inch "Unmanned Undersea Vehicles (UUVs) has proven the concept of autonomous operations that will initially be fielded as the Long Rang Mine Reconnaissance System (LMRS) (AN/BLQ-11). With the size of the 21-inch vehicle comes inherent physical limitations in both payload and energy storage. A larger vehicle allows for more payload and energy storage for longer endurance. These larger vehicles have a promising future. They can extend the operational capability of surface ships and also be an operational capability for the Trident SSGN conversion. These large UUVs can also have significant commercial application, which offers the potential for dual-use capability.

The study would explore the feasibility of designing and operating a large displacement (size to be determined) UUV built to standard open architecture specifications similar to those currently being developed by the Navy for the Mission Reconfigurable (MR) UUV. There are many commonalities between the commercial and military uses of UUVs that could benefit from a joint development program. Some of these include propulsion systems, command and control and high energy density, and the potential for underwater recharging to increase mission duration. The concept would be to build the UUV for dual use as a commercial vehicle and a military development and experimentation platform. Operation of the vehicle part of the time with commercial payloads for private sector customers (e.g., telecommunications/petroleum industry) would defray the cost of vehicle design and fabrication and create a private market upon which industry could capitalize. The remainder of the time, the vehicle would be available at a reduced cost to the Navy to support developmental payloads in Fleet Battle Experiments and NAVSEA 93's Submarine Payloads and Sensors SSGN demonstrations. The reconfigurable payload section would serve to introduce promising technologies to Fleet operators in advance of the formal acquisition program's ability to deliver those capabilities and also provide a platform for commercial payloads.

PROPOSAL

Statement of Work

Background: Research is required into the feasibility of development of an Unmanned Undersea Vehicle Platform that can provide to dual use by the private sector and the Government. Although vehicles have been designed and developed by the private sector, there is no one resource to provide a complete view of the potential for this enterprise and the critical success factors and barriers that must be addressed to provide a complete business case. The NDIA has historical data, some empirical results from similar projects and the knowledge of and contacts with many industry people to provide relevant information for the study to be worthwhile.

Scope: The study has sufficient merit to provide valuable information to our industry partners and the sponsor as a basis for industry members and the Government to make informed decisions as to the tradeoffs required to make such an effort feasible. It can be used as a "jumping off point" by individual companies and the Government to determine if further pursuit of such an endeavor makes good business sense. It is unclear if any definitive business case analysis can be provided. It will provide for an understanding of the critical factors that must be addressed. The study would stop short of providing recommendations on how to address those critical factors, since solutions to the problems would be the subject of proprietary research by individual companies that would allow each to be competitive in the marketplace.

Tasks

Task A. Conduct a review of existing data on the subject that is available from industry NDIA members to determine what historical information is available within the NDIA.

Task B. Determine the additional information required and round out the data by conducting data searches of open sources, interviews and data calls from other private sector organizations (e.g., oil exploration firms, MIT Draper Laboratory, ARL Penn State, Naval Undersea Warfare Center, AUVSI, etc.). Hopefully this will uncover other similar or related efforts on-going. Conduct additional interviews with organizations that may have information to offer.

Task C. Analyze the data and provide a report of findings as to the major issues involved, critical success factors and barriers that must be addressed to provide industry and the Government a measure of the viability of such an endeavor and provide a "roadmap" for how those issues could be addressed.

TERMS

1. Cost. The study is undertaken at no cost to the Government.

2. Proprietary Data. No proprietary data will be included in the study.

3. Government Furnished Information. The Government shall supply any related information from previous or on-going work and provide access to Government personnel involved in that work, if available. The Government will provide "need to know" access to related classified information up to the SECRET level to study people that possess current Government clearances at the SECRET level.

4. Milestones.

a. Complete Approval Process - 30 September 2002
b. Interim Report of Progress to Sponsor at the Spring Conference- March 2003
d. Issue Draft Study Report for Review and Approval - July 2003
e. Approval of Final Study Report - August 2003
f. Presentation of Study Results - September 2003

5. Security Classification. It is expected that the study will be Unclassified. Members of the study group may require access to classified material up to the Secret level during the study.

6. Tasks. The definitive list of tasks and deliverables are per the PROPOSAL section above.

7. Membership. Study membership will be NDIA members from NDIA member companies to be determined. The study will be led by Richard W. Talipsky of EDO Corporation.

8. Modification. This TOR may be modified at any time in writing by mutual agreement of all parties.

AGREED TO:

_______signed _________________ __9/16/02_ __
Bud Dougherty, Chairman, date
NDIA Undersea Warfare Division

_______signed__________________9/17/02_____
John D. Lambert, CAPT, USN date
Program Manager, Unmanned Undersea Vehicles,
Naval Sea Systems Command

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Appendix B - Technical and Other Reference Information

For those viewing this study electronically, parts of Appendix B are in separate electronic file as noted.

This appendix contains technical information and other technical references that may be of interest to some readers desiring additional details of the information the study team gathered during our study process. Where available, links are provided to sites on the World Wide Web where additional information can be obtained.

References for Historical Programs Reviewed in Detail

Tab A - Advance SEAL Delivery System
(NDIA UUV Study 10-4 App B Tab A - Advanced SEAL Delivery System .pdf)
Tab B - Advanced Undersea Surveillance System
(NDIA UUV Study 10-4 App B Tab B - Advanced Undersea Surveillance System.pdf)
Tab C - ARCS (NDIA UUV Study 10-4 App B Tab C - ARCS.pdf)
Tab D - Autonomous Bethnic Explorer (NDIA UUV Study 10-4 App B Tab D - Autonomous Bethnic Explorer.pdf)
Tab E - Autosub (NDIA UUV Study 10-4 App B Tab E - Autosub.pdf)
Tab F - Bluefin (NDIA UUV Study 10-4 App B Tab F - Bluefin .pdf)
Tab G - Hugin 3000 (NDIA UUV Study 10-4 App B Tab G - Hugin .pdf)
Tab H - Large Scale Vehicles (NDIA UUV Study 10-4 App C Tab H - LSV.pdf)
Tab I - Manta Test Vehicle ((NDIA UUV Study 10-4 App B Tab I - Manta Test Vehicle.pdf)
Tab J - Maridan (NDIA UUV Study 10-4 App B Tab J - Maridan.pdf)
Tab K - MUST (NDIA UUV Study 10-4 App B Tab K - Must.pdf)
Tab L - Echo Ranger (OSIRIS) (NDIA UUV Study 10-4 App B Tab L - Osiris .pdf)
Tab M - Seahorse (NDIA UUV Study 10-4 App B Tab M - Seahorse.pdf)
Tab N - Theseus (NDIA UUV Study 10-4 App B Tab N - Theseus .pdf)
*** Tab O** - Navy Transformational Road Map (NDIA UUV Study 10-4 App B Tab O - NTR.pdf)
*** Tab P** - What the Future Holds for UUVs - Underwater Magazine May/June 2000
(NDIA UUV Study 10-4 App B Tab P - UM.pdf)
*** Tab Q** - Study Questions for Southwest Airlines (University of Utah - 1998)
(NDIA UUV Study 10-4 App B Tab Q - SWA.pdf)
*** Tab R** - PPPs American Style - PFI Journal October 2000
(NDIA UUV Study 10-4 App B Tab R - PFI .pdf)

* These Tabs are provide only as electronic files

Useful Web Sites

University of Hawaii Center for Underwater Technology http://www.eng.hawaii.edu/~asl/
Autonomous Undersea Systems Institute http://www.ausi.org/
Autonomous Underwater Vehicles Resources http://www.cacs.louisiana.edu/~kimon/AUV/
Florida Atlantic University Department of Ocean Engineering http://www.oe.fau.edu/AMS/
Robotics at the Space and Naval Warfare Systems Center http://www.nosc.mil/robots/
Naval Postgraduate School Center for Autonomous Underwater Vehicle Research
http://www.cs.nps.navy.mil/research/auv/auvframes.html
United Kingdom Ocean Systems Laboratory
http://www.ece.eps.hw.ac.uk/Research/oceans/index.html