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At the request of the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA), The Navy Unmanned Undersea Vehicle (UUV) Master Plan was prepared, outlining recommended development pathways for UUV systems and technologies for the next decade and beyond. An overall vision of UUVs as integral parts of the battle force is portrayed, with four signature capabilities seen as critical to both near term and long term goals. The technologies required to accomplish these missions were surveyed, and a programmatic roadmap was prepared to develop those capabilities determined to be on the critical paths for implementation.

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UUV Master Plan: A Vision for Navy UUV Development

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Abstract

At the request of the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA), ***The Navy Unmanned Undersea Vehicle (UUV) Master Plan*** *was prepared, outlining recommended development pathways for UUV systems and technologies for the next decade and beyond. An overall vision of UUVs as integral parts of the battle force is portrayed, with four signature capabilities seen as critical to both near term and long term goals. The Maritime Reconnaissance capability provides the means of gathering information from designated areas in a timely and covert manner. Undersea Search and Survey serves both the need for tactical oceanographic data and mine reconnaissance / neutralization. UUVs can also be employed as Navigation / Communication Aids, providing valuable connectivity in the realm of network-centric warfare. Finally, Submarine Track and Trail will provide new capabilities for target engagement. The technologies required to accomplish these missions were surveyed, and a programmatic roadmap was prepared to develop those capabilities determined to be on the critical paths for implementation.*

I. Introduction

A. The Need

Unmanned Underwater Vehicles (UUVs) are a rapidly maturing technology that is on the threshold of playing key roles in the battlespace. With the increasing threats of broad area denial and the ever decreasing resources, autonomous systems provide a promising option for meeting many of the Navy's needs. Critical missions including Intelligence, Surveillance, Reconnaissance, Mine Countermeasures, Tactical Oceanography, Communications, Navigation, and Anti-Submarine Warfare can be effectively addressed with UUVs. The technology and industrial capacity are ready to proceed, yet the fleet has little UUV based capability today.

Worldwide, there are hundreds of UUVs under development or commercially available, providing capabilities to our adversaries in excess of those available to our own fleet. With careful decisions and investments today, UUVs can be positioned to become significant contributors to the Navy's capabilities tomorrow, and be ready for the unexpected future.

B. The Vision

The study team was challenged by ASN/RDA to establish a long-term vision for UUVs with the ultimate question:

What do we want to be able to do using UUVs 50 years from now?

Based upon the current pace of technology and the progress over the last 50 years, the study team developed a Vision of battlefield dominance via unmanned systems. This includes the capabilities of deploying and retrieving objects; gathering, transmitting, and acting upon all types of information; and engaging any target without risk or burden to US forces. That vision is achievable as shown in Figure 1.

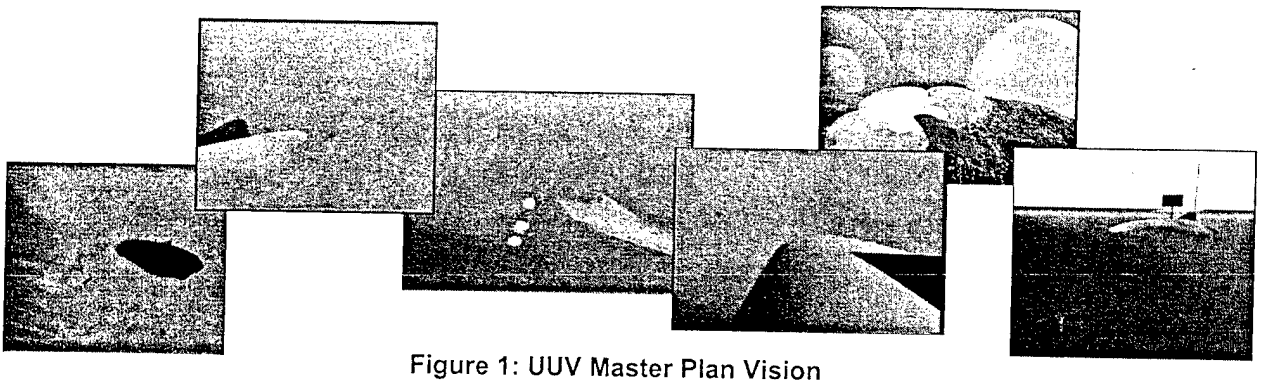

Figure 1: UUV Master Plan Vision

C. The Objective

The objective of the UUV Master Plan is to establish priorities for near-term acquisition programs and technology investment that will fulfill current and projected U.S. naval requirements, while at the same time laying the foundation for long-term applications that may be difficult to imagine.

The plan amplifies upon the challenges of the 1994 UUV Program Plan which established the following four priorities:

1. Near-term stopgap mine reconnaissance capability
2. Greatly improved, higher-performance mine reconnaissance capability
3. Surveillance, intelligence collection, and tactical oceanography capability
4. Research and development of enabling technologies for future UUV missions

Significant portions of that plan are now well on the way to completion. The first priority evolved into the Near-Term Mine Reconnaissance System (NMRS), which completed testing in May 1999 and is now available for contingency operations. The second priority resulted in the Long-Term Mine Reconnaissance System (LMRS) program for which a four-year development contract was awarded in October 1999 leading to IOC in 2003. The UUV Master Plan builds on the original UUV Program Plan, taking into account new missions now projected to be possible given the continued research and development in UUV enabling technologies along with commercial developments.

D. The Approach

The first stage in developing the Master Plan was to generate a comprehensive pool of emerging UUV missions from the near-term (10 years) to the mid- to far-term (50 years). A wide range of potential users were surveyed including those from military, scientific, and commercial fields. During this stage, the goal was to develop an innovative list of applications without regard to technical feasibility, political acceptability, or affordability. The missions were then analyzed and prioritized in accordance with fleet and national needs. They included the following mission areas: Intelligence / Surveillance / Reconnaissance, Mine Countermeasures, Communication / Navigation, Oceanography, Anti-Submarine Warfare, Weapons Platform, and Logistics Supply and Support.

II. Signature Capabilities

Based on these high priority missions, four Signature Capabilities, listed in priority order, were defined:

- Maritime Reconnaissance
- Undersea Search and Survey
- Communication/Navigation Aids
- Submarine Track and Trail

These broad ranging capabilities group together missions with similar operational and technological requirements. Recommended for near-term Navy UUV development, these Signature Capabilities incorporate both existing and new start efforts, address near and mid-term objectives, and provide the technological and operational foundation for long-term goals (Figure 2).

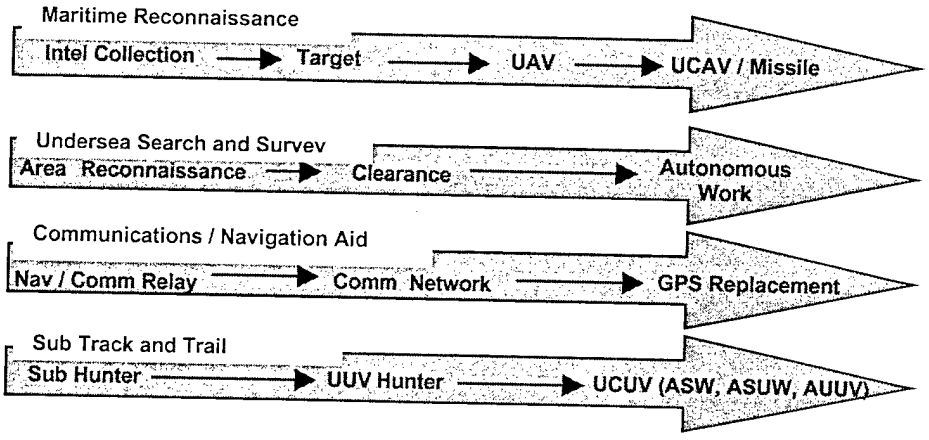

Figure 2: Accomplishing the Vision

A. Maritime Reconnaissance

Rated the number one mission priority, Maritime Reconnaissance (Figure 3) will complement and expand existing Intelligence / Surveillance / Reconnaissance (ISR) capabilities, extending the reach into denied areas, and enabling missions in water too shallow for conventional platforms. Multi-function systems, operating from a variety of platforms, will enable the collection of critical electromagnetic and electro-optic data. The initial implementation may be an ISR periscope type of mission, leading to target designation, launch and coordination of UAVs for battle damage assessment and intelligence collection purposes, and ultimately to engagement via missiles.

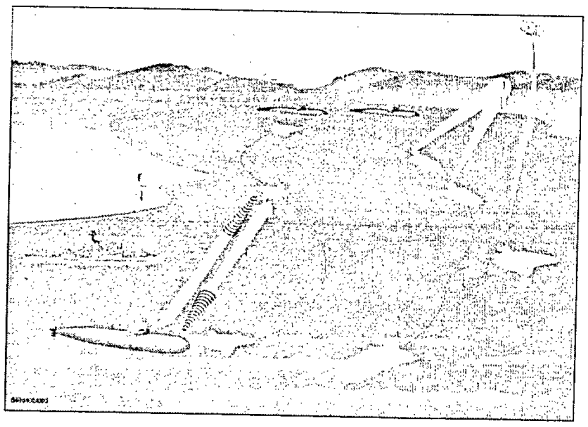

Figure 3: Maritime Reconnaissance

B. Undersea Search and Survey

A classic UUV mission area, Undersea Search and Survey is an extensive capability, encompassing all aspects from Object Sensing and Intervention to Ocean Survey (Figure 4). Both large and small UUV systems will be required to fill the myriad tasks. Some are already fielded or in development, addressing the following needs: clandestine reconnaissance and battle space preparation; in-stride mine reconnaissance and clearance; and hydrographic and oceanographic environmental characterization. This range of UUV systems will support these needs from the surf zone to the deep ocean. These programs will lead to advanced capabilities such as rapid mine clearance and undersea work operations.

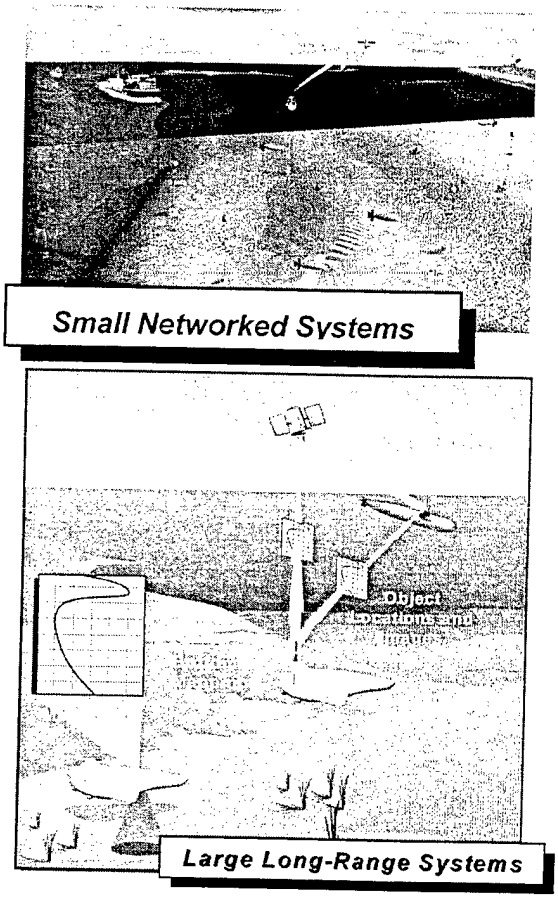

Figure 4: Undersea Search and Survey

C. Communication/Navigation Aids

An essential portion of the UUV mission is the ability to communicate the data collected. The Communication / Navigation Aids (Figure 5) will provide this capability, being the enabling undersea nodes of the Net-centric Warfare Sensor Grid. They will provide connectivity across multiple platforms, both manned and unmanned, as well as the ability to provide navigation assistance on demand. Communication and Navigation modules developed as part of this capability will transition into other UUV systems, reducing the overall developmental burden and risk. They may start as a simple communication/navigation relay, leading to autonomous undersea communication / navigation networks that could augment GPS and communication satellite functions, e.g. in the event of local jamming or other adverse action.

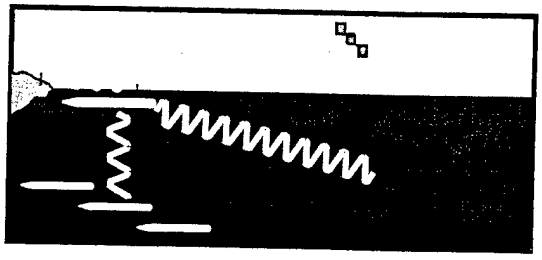

Figure 5: Communication/Navigation Aid

D. Submarine Track and Trail

The Submarine Track and Trail capability (Figure 6) will complement and extend existing anti-submarine warfare capabilities. The vision is to provide a full detection, tracking, and handoff capability using UUVs, ultimately leading to engagement. While full realization of this vision will require long-term investment, there remain near- to mid-term ASW needs that can be well served by precursor systems. This might be mobile cueing function, leading to increasing levels of engagement, first against unmanned systems and eventually, with substantial permissive action links, against manned systems. In the far term, a fully autonomous capability could be realized.

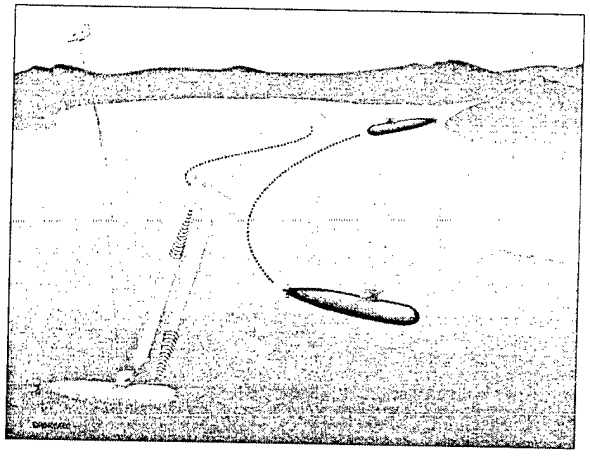

Figure 6: Submarine Track and Trail

III. UUV Development Issues

Effective use of UUVs requires both appropriate technology development and sound engineering. To achieve the four Signature Capabilities, efforts must be made in both areas. Technologies to be developed include autonomy, communications, and sensors. Engineering efforts are required to modularize vehicle systems, reducing the overall costs while increasing capabilities and interchangeability.

A. Technology Issues

Each of the Signature Capabilities has some associated technology issues, resulting in varying degrees of acquisition risk. This can be minimized by either aiming for a partial Initial Operational Capability or by initially accepting a vehicle larger in size and/or with lower performance. These technology risk issues, associated with the ability to support near-term implementation, are summarized in Figure 7. Although the exact coloring of some areas may be debated, the overall trends support the conclusions described in the plan.

Communications for any single UUV is for the most part not a major risk area. Primary issues to be considered when evaluating a mode of communication for a UUV task include available bandwidth, range between source and receiver, covertness, and the infrastructure required. Other communication challenges are associated with multiple vehicles operating together, for example, the architecture associated with a network of 100 UUVs.

	Maritime Reconnaissance		Undersea Search & Survey								Navigation/ Communication Aid			Submarine Track and Trail				
			Object Sensing & Intervention					Oceanography										
	Pass.	Active	Detect (SLS)	Class (SAS)	ID	Neut	Interv.	Bottom Char	Bathy	Volume Meas.	Comm.	Nav.	Data Ex.	Detect	Class	TMA	Trail	Hand-off
Communications	Yellow	Green	Green	Green	Green	Green	Green	Y-G	Y-G	Green	Green	Green	Green	Green	Green	Green	Green	Yellow
Navigation	Green	Green	Y-G	Y-G	Y-G	Y-G	Green	Y-G	Y-G	Green	Green	Green	Green	Green	Green	Green	Green	Green
Energy	Y-G	Y-G	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Red	Green
Propulsion	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green
Mission Equip.	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Sensors	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green
Data Processing	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Autonomy	Yellow	Yellow	Green	Green	Yellow	Green	Red	Green	Green	Green	Green	Green	Yellow	Yellow	Red	Yellow	Red	Yellow

Green: Low risk Yellow-Green: Low-Moderate risk depending on size Yellow: Moderate risk Red: Significant Risk

Figure 7: Technology Risks for Near-Term Implementation

Accurate navigation is not a risk area unless the system is constrained by size and/or the Concept of Operations (CONOPS) prohibits or constrains the frequency of Global Positioning System (GPS) fixes. When those restrictions exist, navigational problems can be addressed via use of an active communications/navigation aid, such as a transponder field or UUV, or by passive means such as terrain matching.

Energy has long been a major consideration due to its effect on the ultimate performance of extended vehicle missions. When surface supplied power is not a viable option, the energy source becomes a major factor in the design and efficiency of a vehicle system. Energy is not the driving force for any of the Signature Capabilities; however, for all operations there is a desire to minimize the size, cost, and signature of the energy and propulsion system. The full Maritime Reconnaissance capability will either require a larger UUV or advanced energy source as will the Submarine Track and Trail capability.

All of the missions described depend on the effective use of sensors, in particular the Undersea Search and Survey and the Submarine Track and Trail capabilities. Development in the sensor arena needs to be concentrated in increasing area coverage rate (ACR), use of passive non-acoustic sensors, and sensor processing. For Undersea Search and Survey, the implementation of synthetic aperture sonar for increased area coverage will have added benefit, but autonomous processing of sonar and optical images to classify mine-like objects and identify mines remains a challenge. For Submarine Track and Trail, there is some risk associated with the miniaturization of sensors, but the more significant risks are associated with sustained speed and endurance, autonomous processing, target recognition, countermeasure rejection, Target Motion Analysis (TMA), and tactics.

Autonomy issues are key to all the Signature Capabilities. The need for long-term independent operation is the basis for both the Maritime Reconnaissance and Submarine Track and Trail missions. Both of these require the ability to transit long distances, detect, assess, and avoid potential threats, and collect information independent of direct human operation. Another aspect of the autonomy question is the operation and coordination of multiple vehicles. This is key to accomplishing large scale Undersea Search and Survey tasks, both for Object Sensing and Intervention and Ocean Survey applications.

B. Engineering Implementation

As important as the technology involved is the engineering implementation of that technology. Engineering considerations are often driven by the size of sensors, energy sources, and payloads, as well as logistic concerns. However, the size and number of vehicles to be used, the overall system costs, and the interchangeability of modules all need to be considered as a critical part in developing the needed capabilities.

Whereas vehicle size is rarely a critical component of the mission, it is generally advantageous to have as small a package as possible to facilitate storage, handling, and general logistics. In most cases, the size is driven by the energy and payload requirements needed for a given mission. Depending on the specific mission requirements, either a few large vehicles can be used or many smaller ones. For instance, the long range requirements of the Maritime Reconnaissance and Submarine Track and Trail missions point to the use of a large single vehicle, while the area coverage requirements of the Undersea Search and Survey point to multiple smaller systems.

An additional challenge for the UUV development is delivering the cost savings of high production rates, not only for the few UUVs that are produced in quantity, but for all UUVs. At low or prototype production rates, typical cost is $1,000 per pound for UUVs. At higher production rates, there is less data, but the trends indicate that costs approach $100 per pound. To achieve the cost benefits of mass production in larger, low production rate systems, a modular approach is recommended. Development of standardized vehicle modules will provide the basis for all the Signature Capabilities, while maximizing the compatibility and transition of components across systems. This concept is being demonstrated by NUWC-Newport, NAVOCEANO, and Florida Atlantic University in construction of their respective vehicles.

The cost benefit and ability to reuse hardware from previous UUV configurations should outweigh any performance penalty for this type of packaging. If modules are common across different UUV capabilities, a "common parts bin" results which significantly reduces overall cost. Use of common hardware modules as well as common software modules will enable more effective transition from legacy systems as needs evolve.

IV. Development Plan

The basic goal of the UUV Master Plan is simple:

Deliver End Items...And Begin Using Them!

Robust UUV capabilities should be delivered to the fleet as soon as possible at minimum cost. There are several parallel UUV developments underway with valid missions. There are also existing capabilities that must be rapidly expanded. UUVs can enhance the effectiveness of U.S. forces while reducing risk at a fraction of the cost of manned systems.

To accomplish this goal, the underlying philosophy is:

Minimize Cost, Maximize Synergy, But One Size Does Not Fit All!

In the near-term, UUVs will continue to vary in size and shape to suit the interfaces of the launch and recovery platform, as well as the intended mission. Therefore, synergy will be a challenge as one size does not fit all. A secondary objective is to minimize UUV rework and associated costs required to maintain or to enhance the Signature Capabilities as new platforms come into service.

A. Roadmap

A programmatic roadmap was created to accomplish the desired Signature Capabilities while rapidly providing UUV capabilities to the fleet in the near term. Key components include the continuation of current programs, the development of UUVs and UUV payload technologies, and the delivery of "end items"--mission reconfigurable UUVs based on standardized modules. Figure 8 outlines the relative timing and sequencing of these capabilities.

B. Recommendations

Beyond the roadmap, the UUV Master Plan contains specific recommendations for the development and implementation of UUVs within the Navy. These include:

1. Complete current UUV development and integration programs and planned upgrades. These systems address high priority needs and the technology, experience, and components of these programs will help form the foundation for future efforts.

2. Continue to execute a balanced technology program for both UUV Payloads and UUV Technology that supports the vision and the four Signature Capabilities. Ensure technologies are advanced that support the needs and reduce the risk of both small modular networked systems and larger high performance modular systems.

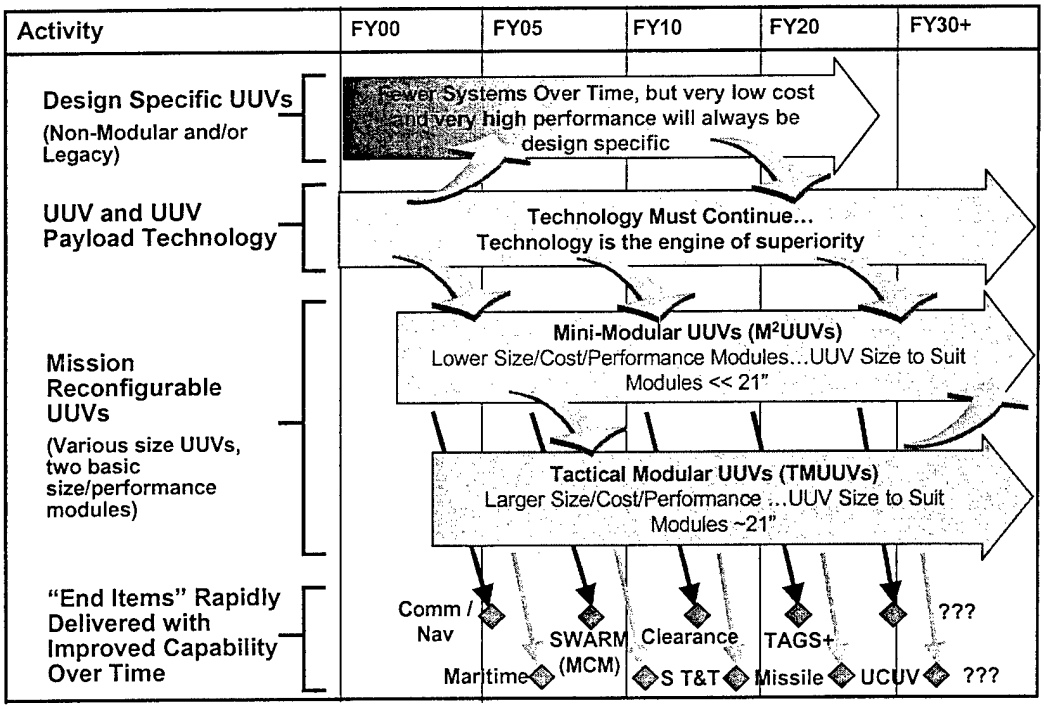

Figure 8: UUV Master Plan Summary Roadmap

3. Develop standards for future UUV module sizes and interfaces. It is expected that with two different module sizes (in the 9" dia and the 21" dia ranges) the majority of future UUV needs can be cost effectively accomplished. The savings associated with standardization of modules (cost sharing in development, operations, and support) and the emergence of capabilities that could otherwise not be afforded will be lasting.

4. Begin outreach to Navy operational, doctrine and training commands to expand and refine employment concepts for UUVs. Address logistical and mission impact of installing and operating UUV systems on combatants early in the ship and UUV acquisition cycle. Continue innovative thinking and review and update this plan periodically.

5. Begin execution of an integrated program to achieve the four Signature Capabilities and begin using UUVs for the benefit of the fleet. Increase coordination between the various UUV developers/users and program managers rather than attempting to combine all UUV programs into one site/location/program.

6. Prior to initiation of any new UUV effort and at major decision points within existing UUV programs, conduct cost-effectiveness trades to determine whether small modules, large modules, or design specific approaches are required.

V. Conclusion

The Navy is strategically positioned to rapidly move forward to achieve the UUV vision. The only barriers are funding and coordination. Technology and industrial capacity are ready to proceed. Despite the fact that there are literally hundreds of UUVs under development or in operational use worldwide, which have logged thousands of dive hours, the fleet has little UUV-based capability today. With careful decisions and investments today, UUVs can become significant contributors to the Navy's capabilities tomorrow, and they will be ready for the unexpected future. The alternative is to fall behind the technical capability of adversaries that decide to exploit existing commercial systems. Now is the time to build on this plan.

Deliver End Items...
And Begin Using Them.

Acknowledgments

The UUV Master Plan was developed by a Core Team of UUV experts from Navy Laboratories and academia:

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The UUV Master Plan Oversight Board represented Stakeholders in UUV development, consisting of members from the following organizations:

Assistant Secretary of the Navy (Research, Development, & Acquisition)

USD(A&T) Naval Warfare

Deputy Assistant Secretary of the Navy (M/UW)

Program Executive Office (Undersea Warfare)

CNO N81

CNO N85B

CNO N86B

CNO N873

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