Executive Summary
Unmanned Vehicles in Mine Countermeasures

In February 1999 the Naval Research Advisory Committee (NRAC) was tasked by the Honorable H. Lee Buchanan, Assistant Secretary of the Navy (Research, Development and Acquisition) [ASN(RD&A)], to conduct a study to determine the application of Unmanned Vehicles (UVs) in Mine Countermeasures (MCM) Operations and to identify alternatives. The tasking included a review of current programs under development, with a view toward determining gaps and overlaps. Based on the findings, the study was to make recommendations for future UV requirements. The Office of the Chief of Naval Operations (OPNAV) sponsor for the study was Major General Dennis Krupp, USMC, Director Expeditionary Warfare (N85). In order to address the broad range of issues associated with UVs in mine warfare, a panel of eight NRAC members was augmented with experts from industry and government as well as three retired flag/general officers with mine warfare experience.

As we look to future joint littoral warfare and the challenge that will face our warfighters, there is little doubt that naval mines will be among the asymmetric threats of most concern. This problem is unique to the Department of the Navy (DON), and while our current mine force is the best in the world, it is only pacing the threat. It must be modernized with more capable systems to not only fill the gaps in today's capability, but also to infuse new capabilities that can meet the anticipated threat in the new millennium. Given the inherent danger in dealing with the naval mine threat coupled with zero public tolerance for casualties and overall initiatives to replace manpower with technology, a review to determine the potential contribution of unmanned systems is timely and appropriate. At the outset it must be noted that there is no "silver bullet" in MCM. The different types of threat mines and environmental conditions that will face our Naval Forces argue for a "system of systems" which is robust and flexible enough to operate in regimes from waters in excess of 200 feet in depth to the Surf Zone (SZ) and Craft Landing Zone (CLZ) on the beach. Technology will not support single platforms or sensors with the required capability, namely to perform the MCM mission across the spectrum of threats.

Additionally, the Commander's operational requirement for dealing with naval mines will be situation dependent. In some cases the location of mines will be sufficient for avoidance, while in other cases neutralization may be necessary. Therefore, an approach that incorporates vehicles and sensors tailored to different functions and communicating together as a network appears to be the most practical, feasible, and least costly way to proceed.

The panel concluded that UVs have an increasingly important role in the MCM mission, and that Naval Forces will therefore require a family of UVs and sensor systems to

provide end-to-end capability over the broad littoral environment. The vehicles will need to be clandestine, affordable, and expendable. The panel underscored that there is neither a capability today against mines in the surf zone, nor a capability for location or neutralization of buried mines from UVs. Finally, it determined the necessity to stay the course with respect to the programs under development today which in some cases are admittedly very large and expensive, in order to field them, learn from them in an operational environment, and fully exploit the technology. Consistent with the foregoing, there are SZ Science and Technology (S&T) programs under way which must be pushed to demonstration soonest. The foregoing will require sustained investment in UV and sensor technology, while concurrently maintaining resources in the developmental systems.

The following are desirable capabilities for UV MCM systems:

- ability to bottom map, assess the environment, and fulfill the detect-to-engage sequence; i.e. detect, classify, and identify (or provide a high degree of certainty) the presence of naval mines, successfully discriminating them from the numerous and ever present non-mine bottom objects (NOMBOs)
- precise navigation which allows for a common tactical picture and provides for safe navigation, mine avoidance, and reacquisition if necessary for neutralization purposes
- speed in conduct of the mission, which applies not only to the speed at which MCM platforms can cover a threat area, but also to the speed of data exchange, processing and fusion of information
- minimum radar, magnetic, and acoustic signatures
- ability to operate in the SZ
- power of sufficient capacity to support propulsion and combat systems (sensors, onboard computer, communications, and neutralization)
- robustness and durability to perform reliably in a hazardous environment
- vehicle size/footprint reduced to the degree that technology can allow to facilitate handling and flexibility with respect to transportation and deployment
- ease of launch and recovery

The panel identified a number of technology long poles relative to the above capabilities. Operating in the very shallow water (VSW) and SZ (40 feet or less) makes underwater communications more difficult and variable. As operations move onto the beach where ground robotics might be applicable, these systems remain to be proven, particularly given the threat posed by buried mines and obstacles. Precise underwater navigation must be achieved in all depths, as must data fusion for a common tactical picture. Assured neutralization remains a high-end challenge; successful hunting is the primary countermeasure today. Challenges associated with the launching of vehicles will extend from a situation of relative ease for those such as unmanned air and surface vehicles operating at great distances from the shore, to one of difficulty for those vehicles that must be inserted into very shallow depths or the SZ, or underwater in moderate sea states.

Finally, as history will reflect, the ability to reduce the size and cost of the vehicles and their sensors while increasing reliability and capability will most likely be the greatest challenge.

As noted earlier, the most economical approach is to tailor the individual elements of the family of vehicles to the domain in which each has the best potential for effective operation. The study concluded that the shallow and deep water domains (40 feet and greater) can be effectively covered by autonomous or remotely controlled low observable surface and underwater vehicles when tactical surprise is not required. When clandestine operations are a requirement, the totally submersible Unmanned Underwater Vehicle (UUV) is the only solution; however, it must be noted that the technical risk for precise navigation and communications will increase significantly. The VSW domain (10 feet to 40 feet) that is covered today by human divers and marine mammals may call for the Unmanned Air Vehicle (UAV) and Unmanned Surface Vehicle (USV), complemented by the UUV at the deep end, and the Unmanned Ground Vehicle (UGV), such as a crawling vehicle at the shallow end. Tactical surprise and survivability of the surface/air vehicles are then factors the operational commander will have to take into consideration. Finally, the SZ and CLZ (0 feet to 10 feet) can only be addressed by the UAV and UGV with associated risks previously discussed.

The panel recommends that a number of steps be taken concurrently to advance the DON capability to use UVs in mine countermeasures:

- Solve key technical problems. Increase S&T effort in biosonars/buried mine detection. Elevate priority of work on sensor data interpretation and fusion. Maintain long-term investments to solve power, acoustic and non-acoustic communications, sensors, precise navigation, and autonomous control. In doing so, leverage investments in UV technologies with Army, industry, and other government agencies and academia.
- Develop a family of UV system capabilities for end-to-end coverage throughout the threat environment. Stress modular design, minimal weight and footprint, and innovative launch and recovery systems, while driving down acquisition and life cycle costs.
- Advance the mine warfare competency. Expedite fielding and demonstration of MCM UV programs under development and acquisition, and incorporate UV technology into future MCM programs.
- Expand the MCM Concept of Operations (CONOPS) to fully integrate UVs into the mine warfare mission. This CONOPS must have end-to-end capability, and be an iterative process as technology evolves. This will, in turn, provide the requirements for S&T programs.

In summary, the UV MCM panel found great potential for UVs to make a sizeable contribution towards meeting the naval mine threat, and recommends that the DON pursue this capability with new emphasis. There must be a concerted effort in sensor

development. Programs currently supported represent only a beginning and must be kept on track while investments are made to work the more difficult technical issues. The area of first priority to develop and demonstrate affordable systems is in the VSW and SZ domains where humans are most vulnerable. These developments must be supported by an integrated CONOPS.