Unmanned Surface Vehicles, 15 Years of Development

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Abstract **– To celebrate the 40th Anniversary of the Oceanic Engineering Society (OES) at the MTS/IEEE OCEANS 2008 Conference in Quebec City a series of review papers were requested from OES technical committee chairs. In response to that request this paper provides a review of the field of unmanned surface vehicles (USVs) and autonomous surface craft (ASCs).**

The paper discusses the enabling technologies that have allowed USVs to emerge as a viable platform for marine operations as well as the application areas where they offer value. The paper tracks developments in technology from early systems developed by the author in 1993 through the latest developments and demonstration programs. The future outlook for USV technology is also described.

I – Introduction

Unmanned surface vessels (USVs) have also been called autonomous surface craft (ASC). As the name implies they remove the operators from the platform and allow new modes of operations. As global positioning systems have become more compact, effective and affordable unmanned surface vehicles have become more capable. Affordable, long range and higher bandwidth wireless data systems have also been key to the rapid growth on USVs for many applications.

Today USVs have been developed and demonstrated by academic labs, corporations and government users. Missions demonstrated include science, bathymetric mapping, defense and general robotics research. Despite this proliferation of proven prototypes there are few USVs on the market or in use, especially compared to their unmanned undersea vehicle (UUV) cousins. This paper concludes with a discussion of some of the emerging new trends in USVs and the challenges to wider adoption of the technology.

II – Early USV Developments

At the MIT Sea Grant College Program, Autonomous Surface Craft (ASCs) were first developed in 1993 and were designed for various missions. The first ASC produced at MIT Sea Grant was named ARTEMIS. This vessel was a scale replica of a fishing trawler used as a platform capable of testing the navigation and control systems required by an ASC. This ASC was then used to collect simple bathymetry data in the Charles River in Boston, MA [1].

One of the primary shortcomings of the ASC ARTEMIS was its small size. This limited its endurance and seakeeping. The field operations of ARTEMIS were limited to the Charles River, a region of limited scientific interest. To produce an ASC with more useful capabilities a kayak platform was examined and converted into an ASC. This new vehicle underwent a series of trials on the Charles River. It was then fitted with acoustic tracking systems and used to follow a tagged fish.[2].

To continue the automated bathymetry experiments begun with ARTEMIS, a new ASC was developed. The specifications of the next ASC were based on a desire to create a system as versatile and useful as a small manned vessel while maintaining a small size to allow for easy deployment and survey operations. The new ASC ACES (Autonomous Coastal Exploration System) was developed during 1996 and 1997 [3]. The completed ASC underwent field tests off Gloucester, MA during the summer of 1997. Upon completion of these trials it was outfitted with sensors suitable for hydrographic survey and successfully completed such a survey in Boston Harbor in December 1997 [4]. Beginning in January 1998 the ASC ACES was returned to the lab for a significant upgrade of its mechanical systems. Modifications and design iterations were tested through the summer of 2000 when the new ASC platform, Fig 1, was renamed *AutoCat* [5].

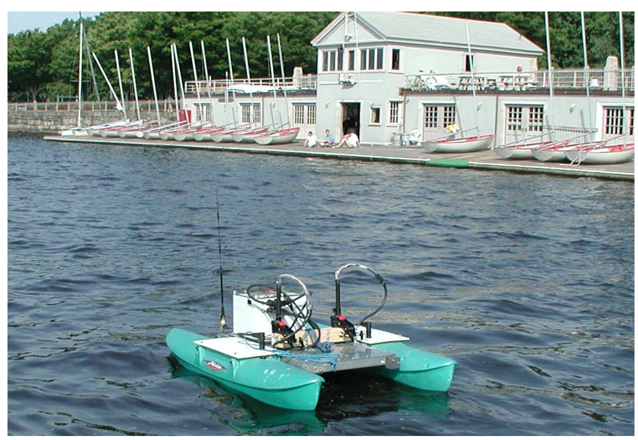

Fig 1. MIT's *AutoCat*, circa 2000

These early developments inspired other USV programs beyond MIT. But it is only in the past few years that USVs

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have proliferated and begun to have an impact in many mission areas.

III – The Past Five Years, Accelerating Development

The US Navy initiated its UUV work well before it focused on USVs. However, the recent release of the Navy's USV "Master Plan" is a sign that the field is catching up in the eyes of this major user [6]. USV's position at the air-sea interface allows them to relay radio frequency transmissions in air and acoustic transmissions undersea. Thus they are a key piece in the vision of networked battlespace. In recent years demonstrations have been conducted using USVs to support moving longbaseline navigation of UUVs [7]. Further evolution of USVs as network nodes in naval applications is likely. Fig 2 shows three "kayak" USVs developed by MIT in operation on the Charles River. Fig 3 shows these same vehicles alongside AUVs for which the USVs provided mobile navigation references.

Fig 2: Three MIT "kayak" USVs operating in a network (*courtesy Mike Benjamin, MIT*)

Fig 3: USVs and AUVs on deck during joint experiments (*courtesy Alex Bahr, MIT*)

Naval USVs have been developed for other military applications such as harbor security or mine sweeping. Frequently, these vehicles are based upon traditional surface vessels, such as rigid hull inflatable. The addition of controls, navigation and telemetry systems can make nearly any small craft into a USV. Most often these are tele-operated by crew ashore or on other vessels. This achieves the important goal of removing the human from harms way but it does not necessarily optimize the use of personnel. These systems are unmanned but their dependence on telemetry makes them more akin to undersea remotely operated vehicles (ROVs) than UUVs.

While some military applications have moved USVs into complex networks and behaviors other applications have focused on more traditional requirements and capabilities. Surveys, for both commercial and scientific purposes have made good use of USVs. "Mowing the lawn" never becomes dull for a USV whereas it can drain even the most dedicated helmsman. Such missions are often executed in a supervisory control approach. Usually the vessel low-level control (e.g. rudder actuation) is computerized while the overall behavior (e.g waypoint selection) is managed by an operator. This approach allows, theoretically, for one operator to oversee many USVs, thus providing a significant "force multiplier" effect.

Survey applications have made use of a variety of hull forms. Numerous catamaran type USVs have been developed to support academic interests [8,9]. An Italian catamaran USV, called SESAMO, was used in Antarctica in support of oceanographic research [10]. The stability, payload capacity and ease of deck access make catamarans a compelling choice for academic USVs. The ROAZ vehicles from Portugal, like SESAMO, exemplify the general arrangements. Fig 4 shows the ROAZ II, which has supported surveys and networked operations with UUVs [11].

Fig 4: The ROAZ II USV (*courtesy Hugo Ferreira, LSA*)

While these small catamaran platforms have some advantages they are being superseded in commercial survey applications by even more intriguing designs. C&C Technologies in collaboration with ASV, Ltd. are developing a semi-submersible platform for hydrographic survey applications, Fig 5 [12]. This design derives from the small waterplane area twin hull (SWATH) approach, but uses only a single hull. The majority of the USV is submerged with only a mast for communications and air intake protruding above water. This design allows for the use of internal combustion propulsion systems, large payload volumes and excellent passive stability. C&C Technologies has used AUVs successfully for commercial and scientific surveys [13] and similar applications of this USV can be expected.

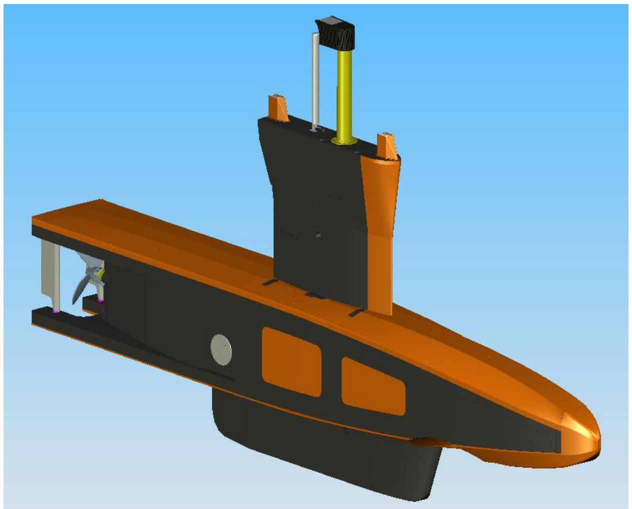

Fig 5: A new USV Design for survey applications (courtesy C&C Technologies/ASV Ltd.)

III – The Wave of the Future

USVs are finally becoming a recognized technology for application to mission needs and further research and development. Technology is advancing USVs toward "persistent presence." Challenges to wide use of USVs remain, especially in the policy arena.

Fig 6: A prototype sailing USV (courtesy Unmanned Ocean Vehicles, Inc.)

As USVs have become accepted, the desire to deploy them for extended periods has driven innovation in technology. All major sources of ocean "renewable energy" are under development. Wind, solar and even wave energy have been used to propel prototype USVs. Both wind and wave powered USVs are under development at small companies. Unmanned Ocean Vehicles (UOV) Inc. has developed prototype unmanned sailing vessels. Equipped with rigid sails and solar cells for onboard power UOV has designs ranging from 15 to 27 feet in length. The prototype, Fig 6, has demonstrated autonomous operation, wireless communications capability, electrical power generation, and sensor data collection. It remains a test bed for systems integration, and experimentation, including alternative wing and sail configurations and control mechanisms. With these results UOV has recently been awarded a Phase II Small Business Technology Transfer (STTR) from the Naval Sea Systems Command [14].

While sailing vessels have centuries of history, a much newer technology has emerged. Liquid Robotics has pioneered a USV that harnesses energy from wave action for its propulsive needs. Solar panels power onboard electronics allowing for extremely long endurance [15]. Wave Glider prototypes have demonstrated extended deployments of 142 days during which over 2500 nautical miles were traveled. The vehicles exhibited excellent performance throughout this demonstration of near persistent presence. This new approach to USVs presents a minimized silhouette, making this platform of great interest for surveillance activities. Its long endurance and scalable payload capacity makes it a likely candidate for many scientific applications as well.

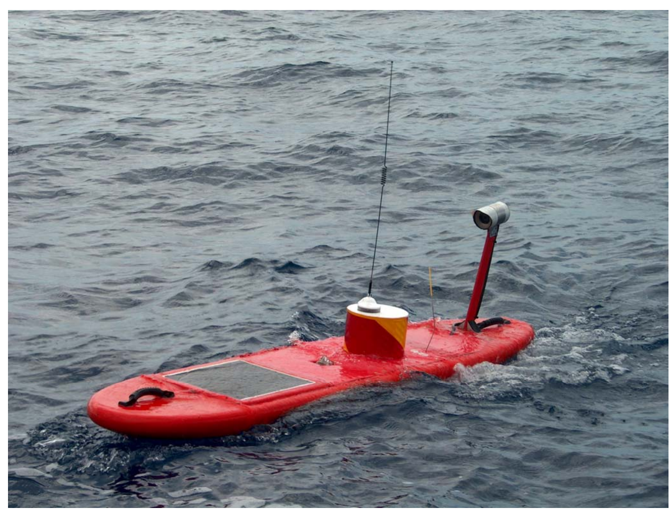

Fig 7: A Wave Glider USV (courtesy Liquid Robotics)

As USVs achieve longer endurance it is possible to envision a new era of ocean observing. Expensive fixed moorings may soon be replaced by teams of USVs. Onsite vehicles could keep station in a desired location while replacements are being serviced ashore and autonomously transiting to relive the unit on duty. Meanwhile coordinated groups of USVs could be directed to intensively study realtime conditions in the ocean. Many scientific and military missions will benefit from such operations. Wider adoption of long range USVs will likely lead to reduced capital costs and thus additional applications of the technology. Comparisons to consumer electronics (e.g. rapid price drop of DVD players) are not entirely appropriate but the potential for USV persistent presence to reshape ocean science and defense is clear.

While the technology potential of USVs is bright, there is a looming policy challenge. Unlike UUVs, which largely avoid the issue of competing users of the sea, USVs must be ready to interact with all manner of shipping. Research and development programs are addressing the technical questions posed by the intersection of USVs and the nautical rules of the road [16]. Initial results are promising but technology alone will not be the answer.

There have been significant efforts underway to develop technical standards for UUVs [17]. These efforts, led by ASTM Committee F41, have broadened to approach all manner of unmanned maritime systems. Recently a sub-committee has been formed to address rues and regulations. It is hoped that the output of this activity will offer a path forward blending policy and technology solutions and enabling the wider adoption of this potent technology.

Acknowledgments

This paper is simply a brief overview of a substantial field. The author appreciates the courtesy of images provided by colleagues and begs the indulgence of those programs and developers who may not have been represented here.

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