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Have robot, will travel

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ABSTRACT

My professional career has largely revolved around developing and operating Autonomous Underwater Vehicles (AUVs) for ocean science. It has proven immensely gratifying; there are very few other enterprises that offer a similar combination of interesting people, tough intellectual problems, opportunity to work in the most remote and beautiful parts of the planet, and the satisfaction of contributing to an important endeavor. This article tracks my research and development activity, starting with early technology exploration when research funding was thin, to my first field programs, to leadership of larger enterprises where AUVs became elements of integrated observation-modeling systems. Not all of the activity was in the laboratory; as the platforms matured, and applications become better defined, commercialization activity became the dominant vector of AUV capability to the larger community. Most recently, my AUV work has focused on a new generation of long-range AUVs and the biological investigations they are designed to enable. Today AUVs are accepted oceanographic tools, and science users are increasingly sophisticated. However, in the late 80s, when I started, it was not at all clear how oceanographers would employ AUVs, or what operational AUVs would look like.

1. Introduction

Little in my academic preparation suggested a career in marine robotics. My Ph.D. was in physics, and my graduate work revolved largely around fabricating sensitive quantum mechanical sensors.

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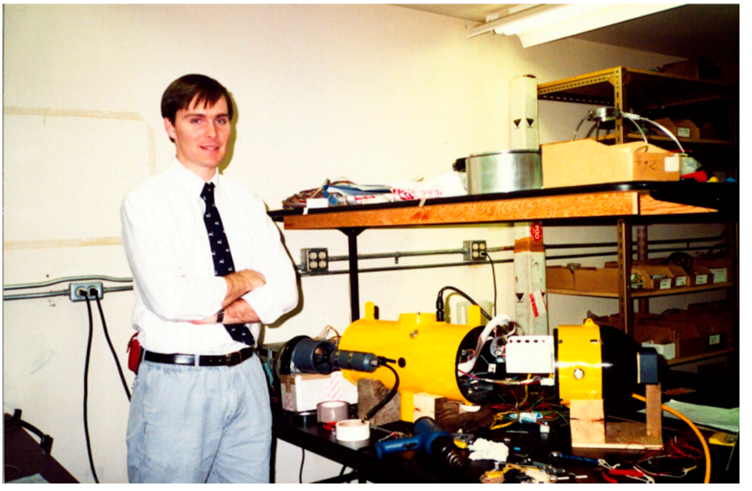

Fig. 1. Building the Sea Squirt in early 1989. This picture was taken at International Submarine Engineering, which hosted me for two months. The President, Jim McFarlane Sr., told me that if I could get any of his employees interested, they were welcome to help build the vehicle. By the end of the visit we had the vehicle running in ISE's test tank. My time at ISE was an accelerated (and really fun) apprenticeship in the art of building undersea vehicles.

When I left the world of low temperature physics, superconducting magnetometers and ultra-low magnetic fields, and started building AUVs, the only ocean engineering course I had taken was in sonar design. However, I knew the folks at the Massachusetts Institute of Technology (MIT) Sea Grant College Program – they had funded part of my Ph.D. work – and I had been following their efforts to get an AUV program started with some envy. Chrys Chryssostomidis, the MIT Sea Grant Director, and Norm Doelling, his Associate Director, had been successful in assembling a loose consortium of organizations interested in AUVs, but progress developing an AUV was slow. In 1988, they decided they needed someone to run the effort. I found out about the position from a leaflet in MIT's Infinite Corridor. I called immediately. By the end of that day I had a new job, to start and run the MIT Sea Grant AUV Laboratory.

In the late 80s, AUVs were technical curiosities with a record of demonstrations but no adoption (Busby, 1990). Today AUVs can be purchased from several companies, and are routinely used by ocean scientists, industry, and the military. My experience developing AUVs parallels this maturation of marine robotics. *Sea Squirt* (Bellingham et al., 1989) was my first vehicle, and was a technology testbed, or more specifically a software testbed. Following the *Sea Squirt* were several variants of *Odyssey*, *ALTEX*, *Dorado*, *CETUS*, and *Tethys* class AUVs as well as involvement with a series of platforms produced at Bluefin Robotics. While the *Sea Squirt* operated in sheltered environments like the Charles River for missions of a couple of hours at most, subsequent platforms were operated at sea from the Arctic to the Antarctic. The *Tethys* AUVs runs missions over three weeks in length, controlled remotely via occasional satellite communications, covering distances of up to 1800 km. However, for me it all started with *Sea Squirt* (Fig. 1).

2. Technology exploration and early AUVs

The principle questions *Sea Squirt* was designed to answer were simultaneously extremely vague yet critically important. They were: when building an AUV, what aspects are hard, what aspects are easy, and how do these map to potential applications? My expectation was that mission-level control was the outstanding problem for mobile undersea robots. This was a logical assumption: mission-level control was the unique aspect of an AUV, encompassing the decision-making capability that justifies the use of the word 'autonomous'. In fact, this problem proved to be far more tractable than some other challenges, like navigation, communication, data management, and sensing, to name a few. Even on the limited processors of the late 80s and early 90s, we found that our variants (Bellingham et al.,