Patents Introduction

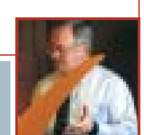
"Draper has an established patent policy and understands the value of patents in directing attention to effective individual accomplishments in science and engineering."

William Elias,
Draper's Legal Counsel

Draper Laboratory was formed to contribute to scientific research and technological development, and has a long tradition of technical creativity. The disclosure of inventions is an important step in documenting Draper personnel's creative efforts, and is a requirement under Laboratory contracts (and by an agreement with Draper that all employees sign). Draper has an established patent policy and understands the value of patents in directing attention to effective individual accomplishments in science and engineering.

This past year, Draper has taken several steps to enhance the use of its intellectual property portfolio and to assist and recognize Draper employees who generate patentable and innovative technologies. Draper has created an internal Technology Licensing Office that is focused on increasing Draper's technology transfer to the commercial sector, and is increasing internal education efforts to augment employees' understanding of patents and intellectual property issues. In tandem with these efforts, Draper created Navigator Technology Ventures, a subsidiary that concentrates on forming startup companies around technologies created by Draper and other institutions.

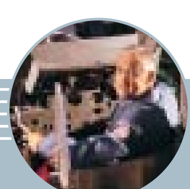
Draper continues to receive and pursue patent action on a great variety of high-quality invention disclosures. We expect the pace of the creation of intellectual property assets to continue to increase, and to assist Draper in pursuing its core mission and in performing work for its sponsors.



Draper's Best Patent winner in 2000 is this year's featured patent:

Pelagic Free-Swimming Aquatic Vehicle

The following pages contain an overview of the technology covered in the patent, followed by the official patent abstract issued by the U.S. Patent Office.



Pelagic Free-Swimming Aquatic Vehicle

No. 6138604 Issued 31 October 2000

Winner of Draper's 2000 Best Patent Award

Jamie M. Anderson, Peter A. Kerrebrock, Peter W. Sebelius

Overview

A pelagic free-swimming aquatic vehicle includes a rigid forebody with a predetermined volume, a watertight chamber in the forebody, and a flexible afterbody with a lesser volume than the forebody. It includes a maneuvering and propulsion structure and a drive system to drive the structure with a traveling sinusoidal wave motion.

The invention resembles the shape of a pelagic fish or marine mammal with a longitudinal mass distribution similar to that of the natural model. It consists of a rigid or semirigid forebody occupying approximately the first 60% of the prepeduncular length (the prepeduncular length refers to the length from the forward tip of the vehicle to the hinge of the caudal fin) with a free-flooding flexible tail structure. This allows swimming and turning motions that closely resemble that of pelagic fish and marine mammals.

A rigid forebody may comprise a single pressure hull or an assemblage of smaller pressure hulls nested in a hydrodynamic fairing. A semi-rigid forebody may comprise an assemblage of smaller pressure hulls joined by hinges and nested in a flexible fairing. These hinges would be driven by mechanical actuators to cause curvature as the vehicle swims. The pressure hull(s) will contain equipment that must stay dry, and will also provide substantial buoyancy to float the weight of the vehicle. If the vehicle is to operate at shallow depths, a single pressure hull conforming to the shape of the forebody of the natural model is preferred, since it provides the greatest volume for packaging dry components, and its shape is an efficient structure under modest hydrostatic load. A domed closure at the aft end of the pressure hull will be used where it joins the flexible tail structure. If the vehicle is to operate at deep depths, one or more cylindrical or spherical pressure hulls can be packaged in a hydrodynamic fairing with buoyant rigid structural foam filling the interstices. This reduces the useful dry volume in the pressure hull(s), but makes the pressure hull(s) capable of resisting greater hydrostatic load.

The flexible tail structure contains actuators that cause the tail to bend in a swimming motion, and supports the caudal fin, which is actuated similarly. A possible tail structure embodiment comprises a series of planar rigid or elastic links with devices to create moments at the hinge points between the links and at the caudal fin. It is expected that a minimum of four rigid links (including the caudal fin) or fewer elastic links will be necessary to replicate swimming motion adequately. The links could be driven by electric motors and wire rope tendons running through a series of sheaves. Or, a recirculating hydraulic system in the pressure hull(s) could provide fluid power to hydraulic cylinders that drive the links. A third arrangement would use motors to drive master hydraulic cylinders in the pressure hull(s), which would drive slave cylinders on the links. A fourth arrangement would use a single flexible beam in lieu of the rigid links, with piezo actuators or synthetic muscles fastened to the beam to cause it to bend appropriately. An additional actuator would be required to cause the caudal fin to actuate.

In all embodiments, the flexible tail structure would be surrounded by a flexible body comprising a series of transverse plates that define the outer shape of the tail body and provide necessary buoyancy in the tail. A flexible skin stretched over the plates would provide a smooth hydrodynamic surface. The plates would be made of a buoyant rigid structural foam fastened to two flexible battens that run the length of the tail, one dorsal and one ventral. The plates would be so spaced on the battens to allow the battens to bend between them. A void, or tunnel, running down the centerline of the body through the plates and between the battens would accommodate the links or flexible beam. If links were used, each would be attached to the battens in one location, causing the flexible body to bend smoothly. If the beam were used, it would be fastened to the flexible body continuously along its length, since it bends smoothly. In a second arrangement, the flexible body would be made from an elastomeric material (such as, but not limited to, polyurethane rubber). Rigid buoyant foam blocks would be embedded in the tail to provide buoyancy as required. The rigid links or flexible beam would occupy the center plane of the tail to provide actuation.

Additional fin elements may be included to enhance system performance, such as pectoral fins on each side of the body for dive plane (pitch and depth) and vehicle roll control. Dorsal and ventral keel-like fins may be added for stability and erectable fins to increase the projected side area for maximum profile during rapid maneuvering. Finally, specialty structures such as finlets and small lifting protrusions may be added for flow straightening and to prevent cross-flow in the posterior portion of the vehicle near the main propulsor.

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United States Patent [19]

Anderson et al.

[11] **Patent Number: 6,138,604**

[45] **Date of Patent: Oct. 31, 2000**

[54] **PELAGIC FREE SWIMMING AQUATIC VEHICLE**

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[73] Assignee: **The Charles Stark Draper Laboratories, Inc.**, Cambridge, Mass.

[21] Appl. No.: **09/085,256**

[22] Filed: **May 26, 1998**

[51] **Int. Cl.**[7] **B63G 8/18**

[52] **U.S. Cl.** **114/332**; 440/15; 114/337

[58] **Field of Search** .... 114/312, 333, 114/337, 313, 332, 144 R, 126; 440/14, 15

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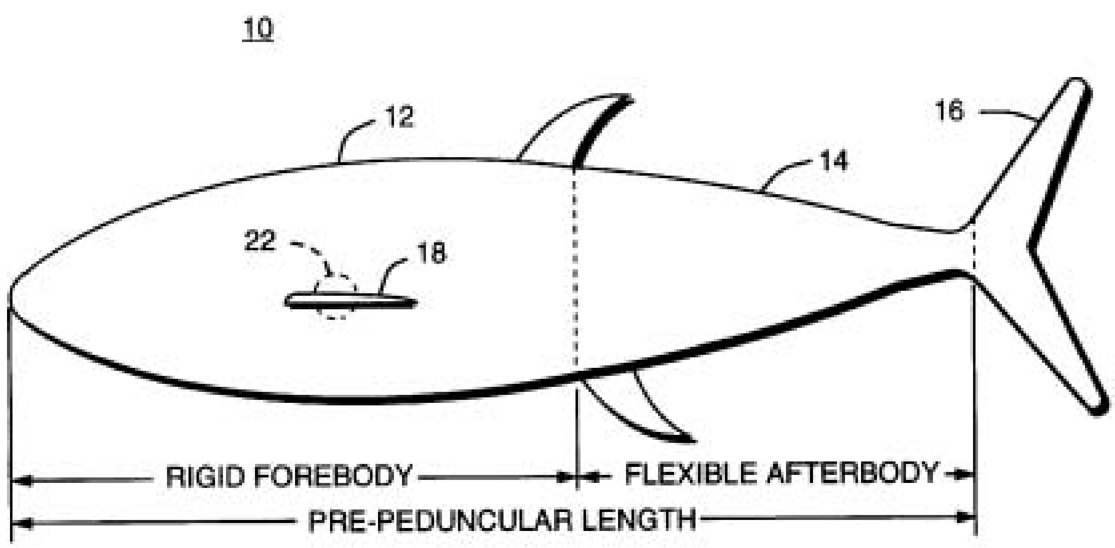
Primary Examiner—Stephen Avila
Attorney, Agent, or Firm—Iandiorio & Teska

[57] **ABSTRACT**

A pelagic free swimming aquatic vehicle includes a rigid forebody having a predetermined volume; a watertight chamber in the forebody; and a flexible afterbody having a lesser volume than the forebody and including a maneuvering and propulsion propulsion structure and a drive system for driving the structure with a traveling sinusoidal wave motion.

24 Claims, 14 Drawing Sheets



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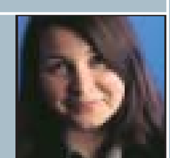

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Biographies

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is a Senior Member of the Technical Staff and has been with Draper Laboratory since 1996. She is the Group Leader for Vehicle Systems in the Mechanical and Instruments Division. She is Principal Investigator for the VCUUV, a prototype fish-like autonomous underwater vehicle designed to study the propulsion and maneuvering characteristics of flexible hull vehicles. She managed and supervised all aspects of vehicle concept proposal, design, fabrication, budget, and staff. She was also Mechanical Design Task Leader for the Wide Area Surveillance Projectile (WASP) project, an autonomous aerial vehicle that is deployed by launching inside a munition subjected to 15000 times the acceleration of gravity. Previously, Dr. Anderson was a research assistant in the Ocean Engineering Department at MIT. Dr. Anderson has co-authored several papers for the *Journal of Fluid Mechanics* and conference publications. She received a BS in Mechanical Engineering from the University of California, San Diego (1989) and MS and PhD degrees in Oceanographic Engineering from MIT and Woods Hole Oceanographic Institution (1992 and 1996, respectively).

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is a Senior Member of the Technical Staff in the Vehicle Systems Group. He is responsible for performing mechanical design and analysis tasks in a variety of subjects related to undersea, ground, and aerial systems. Mr. Kerrebrock recently served as Lead Mechanical Engineer and Naval Architect on the VCUUV Project, and was also currently Mechanical Task Leader for the Tactical Mobile Robotics and Autonomous Systems IR&D projects. Prior to that, he served as an Alternate Lead Mechanical Engineer in the DARPA AMMT UUV program. He recently co-led Draper's mechanical and naval architectural efforts in the LMRS IPT and COEA and the LMRS UBD design effort that followed. Previously, Mr. Kerrebrock was a contributor to the SOMSS and AVC programs for the development of submarine torpedo tube-launchable UUVs. He also served as Principal Investigator of an IR&D project to investigate advanced energy storage and conversion systems for UUVs, and as Mechanical Task Leader for Draper's concerns in the U.S. Navy DSRV program. Before joining Draper Laboratory in 1989, Mr. Kerrebrock was a Mechanical Engineer at the U.S. Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island, where he was involved in the development of thermal torpedo propulsion systems. During the torpedo MK 48 ADCAP program, Mr. Kerrebrock directed all propulsion system dynamometer testing, evaluation, and failure analysis from pre-ADM through FSED. Mr. Kerrebrock received a Sustained Superior Achievement Award for his work on the ADCAP program.

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is Group Leader for the Mechanical Engineering Group at Draper Laboratory, and is responsible for all mechanical design and analysis functions performed by a group of 14 mechanical engineering professionals. He is also responsible for the performance of four Draper Laboratory Fellows performing graduate level research. Previous assignments at Draper include: Associate Director of the Mechanical Design/Analysis Directorate and Section Chief of the Vehicle Design Section, where he was responsible for all Submersible Vehicle Design activities and vehicle design R&D. He also served as Technical Director for the $28M UUV project, Project Manager and Task Leader for the $6M Hydrodynamics/Hydroacoustics Technology Center, and Project Manager/ Technical Director for the Super Conducting Super Collider Project at Draper. Previously, Mr. Sebelius was the Mechanical Technical Director for the design, fabrication, and testing of a deep diving oceanographic system, supervising professional and technical personnel in the performance of a $6.5M effort on the project. He served with the U.S. Navy (1976-1982) as a commissioned officer, engineering duty. He was a member of the U.S. Navy Reserve (1982-1998), and recently retired with the rank of Commander from the U.S. Naval Reserve. Mr. Sebelius received degrees in Naval Architecture and Marine Engineering from MIT (1976).