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14. ABSTRACT

The goal of the PowerSwim project is to develop a human-powered swimming device to enhance the speed and range capabilities for today's combat swimmers. To achieve this goal, a human-powered oscillating-foil device has been developed. The device, which utilizes lift-based propulsion instead of the more typical drag-based propulsion associated with swim fins, allows the combat swimmer to travel faster and farther than previously possible. Several devices were built and provided to combat swimmers for field trials. The objectives of the project were met, as the

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Report Title

Final Report
PowerSwim: A Novel Concept to Enhance Speed and Range of Combat Swimmers

ABSTRACT

The goal of the PowerSwim project is to develop a human-powered swimming device to enhance the speed and range capabilities for today's combat swimmers. To achieve this goal, a human-powered oscillating-foil device has been developed. The device, which utilizes lift-based propulsion instead of the more typical drag-based propulsion associated with swim fins, allows the combat swimmer to travel faster and farther than previously possible. Several devices were built and provided to combat swimmers for field trials. The objectives of the project were met, as the combat swimmers were able to achieve significantly higher swimming speeds at a reduced metabolic cost.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in peer-reviewed journals: 0.00

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals: 0.00

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

(d) Manuscripts

Received	Paper

TOTAL:

Number of Manuscripts: 0.00

Books

Received	Paper

TOTAL:

Patents Submitted

1. Apparatus and Method for Attaching Equipment
9/2/2006
2. Tac Board Apparatus; Apparatus and Method for Efficient Swimming
11/28/06
3. Apparatus and Method for Efficient Swimming
8/6/07

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:.....	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:.....	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

PowerSwim: A Novel Concept to Enhance Speed and Range of Combat Swimmers Phase 2

Final Report

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Problem Statement and Project Goals

The primary program goal for Phase 2 of the PowerSwim program was to minimize the total metabolic cost of swimming 1 km. This distance was chosen as a typical operational distance for combat swimmers, but any advantage afforded by the new PowerSwim device should apply equally as well, if not better, over longer distances. The standard for comparison was the total metabolic cost of swimming 1 km with fins. It was assumed that total metabolic cost is proportional to total oxygen consumption by the diver, so total oxygen consumption was used as the measure for metabolic cost. The goal was to reduce the total metabolic cost of a 1 km swim, with a target reduction of 50%.

A secondary goal for Phase 2 of the PowerSwim Program was to redesign the PowerSwim device to be compatible with combat swimmer's standard issue dive gear. The most challenging component of this dive gear was the Drager rebreather unit, which is a somewhat bulky device that the combat swimmer wears mounted to their chest. The PowerSwim device developed in Phase 1 of this program interferes directly with the Drager unit, and, is therefore, not an acceptable solution for field use.

Project Background

The DEKA solution was built upon an oscillating foil device (OFD) concept generated over 30 years ago called the Aqueon. The original Aqueon, shown in Figure 1, is a device that is comprised of two foils, and a frame to attach itself to a swimmer's lower legs.

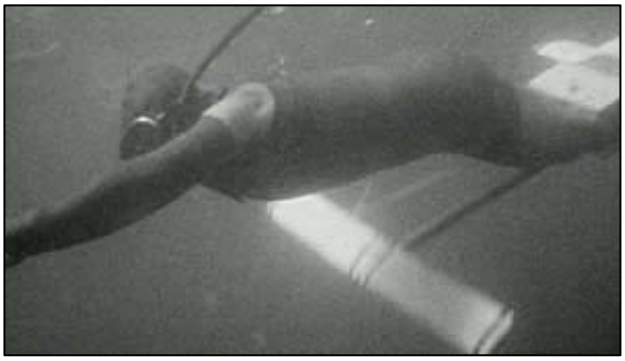

Figure 1: Diver Wearing Original Aqueon

The front foil is the main propulsive element, and is hinged at the leading edge, and "spring centered" to allow for a variable angle of attack. The rear foil is fixed in position. As the swimmer pivots his lower legs forward and backward, the OFD's frame is driven through an arc-wise motion, shown in Figure 2, with a center of rotation somewhere in the vicinity of the his ankles. The propulsive foil is the farthest element from the center of frame rotation, so that it travels a large distance with relatively small motions of the legs—allowing the swimmer to maintain a streamlined posture while powering through the water.

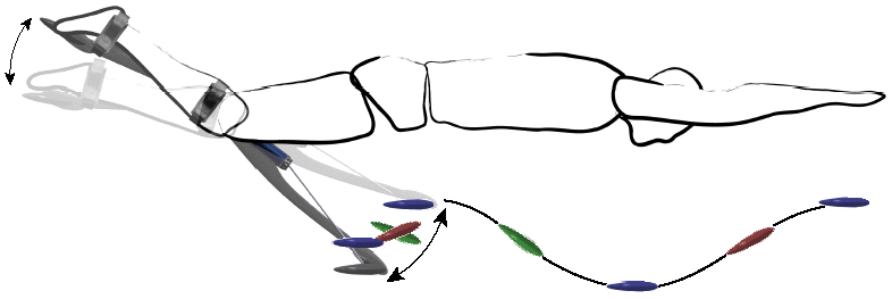

Figure 2: PowerSwim Oscillating Foil Device

A well refined, comfortable, and efficient version of the OFD was developed during Phase 1 of the PowerSwim program. This design evolution consisted of four generations (design/build cycles). While the Phase 1 PowerSwim device did largely meet the performance goals for the Phase 2 project, it was not compatible with the combat swimmer's standard issue Drager rebreather. A pair of the Phase1 PowerSwim devices can be seen below, in Figure 3.

Figure 3: Two (2) PowerSwim Phase1 Devices

Summary of Project Activities

During Phase 2 of the PowerSwim program, a fifth generation oscillating foil device (OFD) was developed and built that showed a significant reduction in the metabolic cost of swimming 1 km compared to fins, allowed for faster speeds, and was compatible with current user equipment (specifically the Drager). This device is called the V-5 and is shown in Figure 4 below.

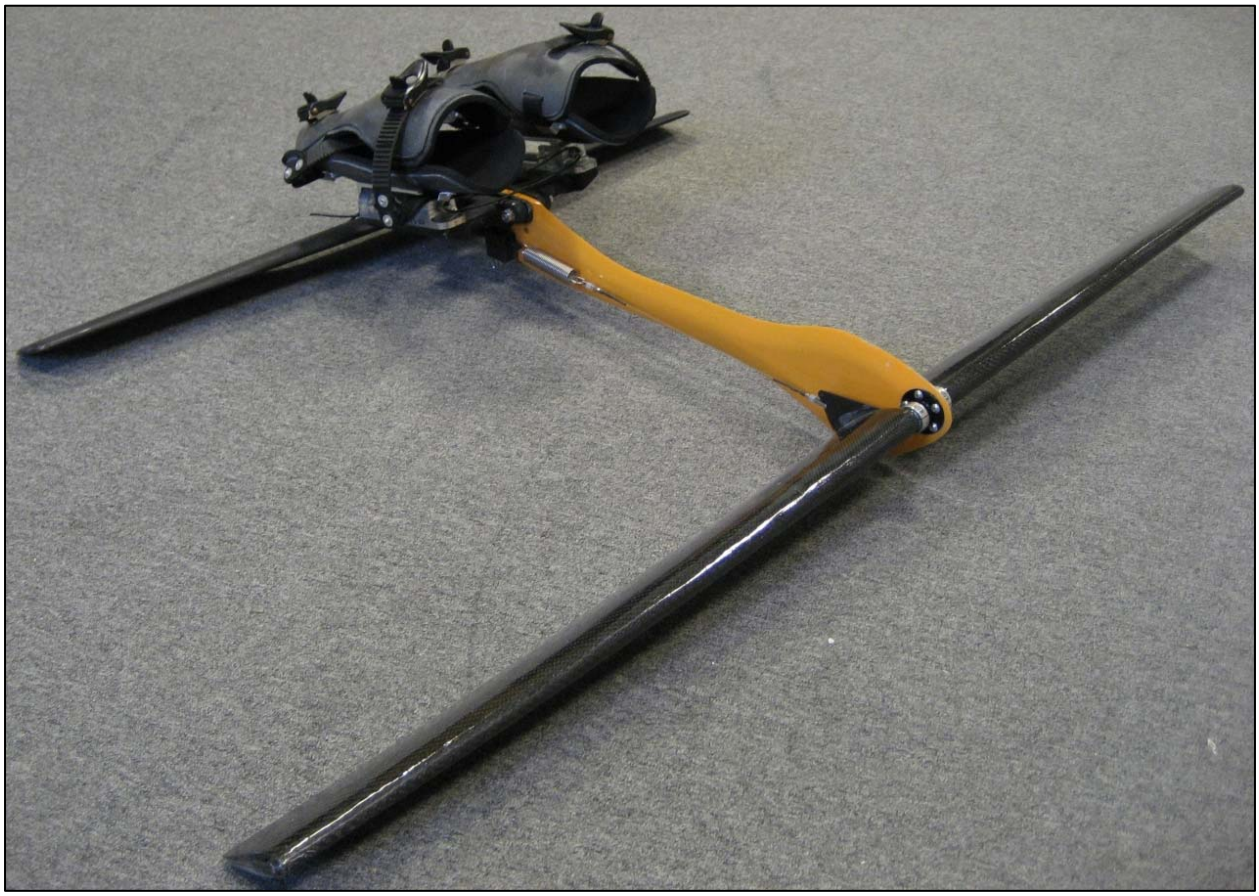

Figure 4: V-5 OFD device with leg cuffs mounted

A primary advance in Phase 2 was to improve performance of the device while actually *shrinking* the fuselage length (necessary to ensure the device did not interfere with the Drager breathing device used by divers). This was done by using a longer wingspan and an optimized wing design that provided improved thrust even though the heave angle was reduced significantly. The results of testing the V-5 units versus swim fins are shown in Figure 5 on the next page.

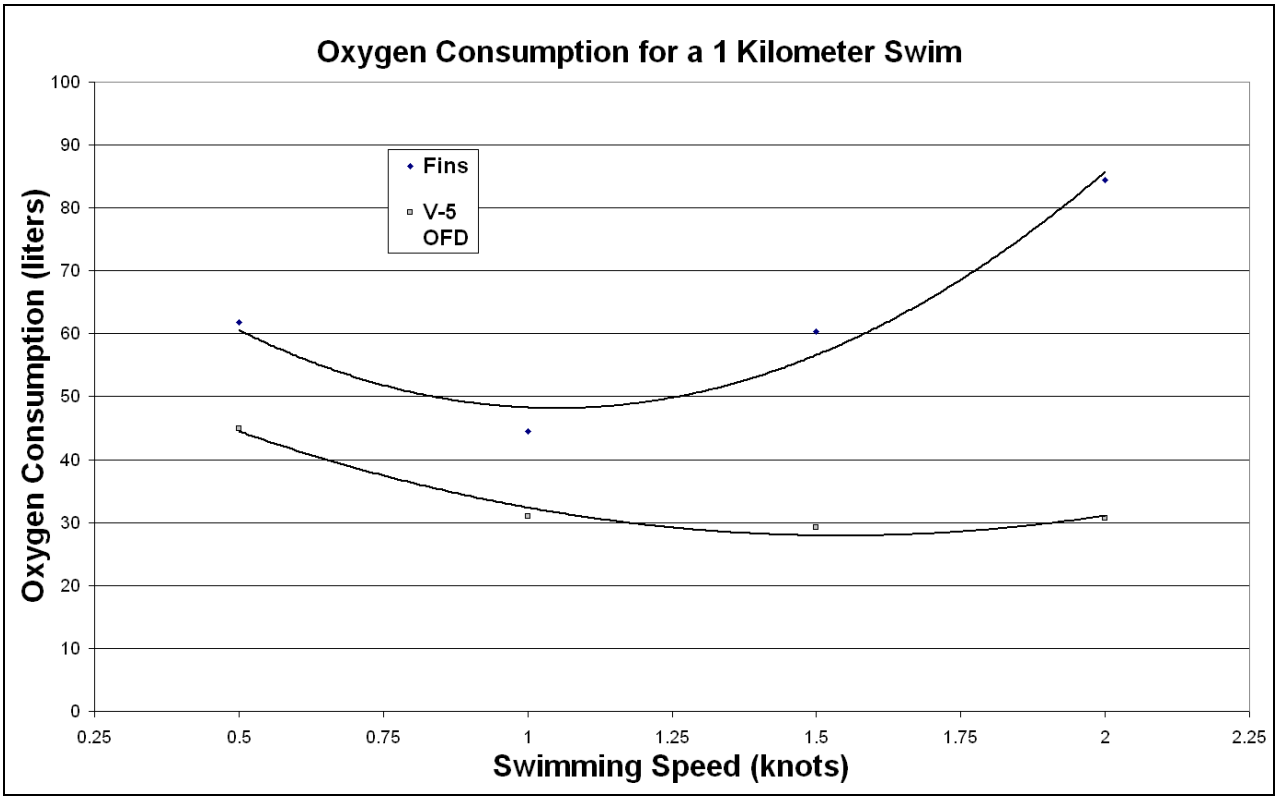

Figure 5: Total oxygen consumed over the course of a 1 kilometer swim using fins and OFD at various swimming speeds. The use of the OFD instead of fins results in considerably less oxygen consumption. In addition the OFD is more efficient at higher speeds allowing for quicker swimming times for the same amount of oxygen.

Summary of Project Results

The goals for the PowerSwim Phase 2 Project were met.

Decreased Metabolic Cost of Swimming, and Higher Sustainable Swimming Speeds
A PowerSwim device was developed that was demonstrated to significantly reduce the metabolic cost of swimming, while increasing swimming speed capabilities.

PowerSwim Compatibility with Combat Swimmer's Dive Gear
The Phase 2 PowerSwim device was also demonstrated to be compatible with the standard-issue Drager rebreather unit, as well as the rest of the standard combat swimmer's typical gear.