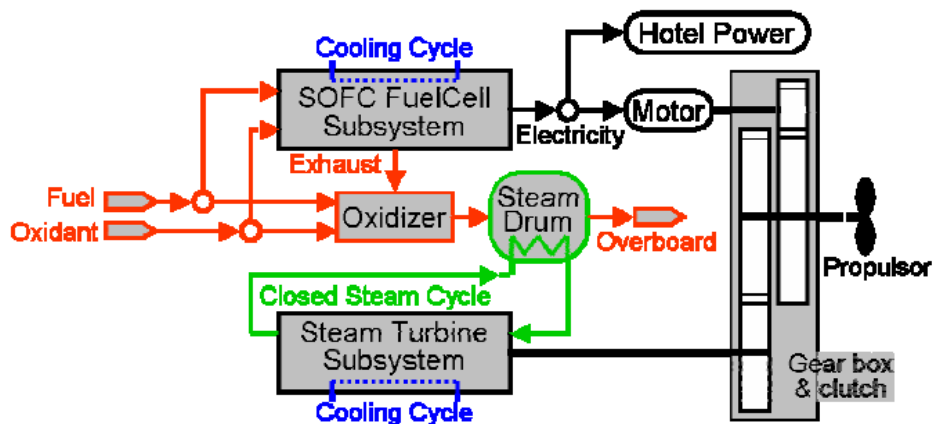




## Project Fact Sheet

# Hybrid Fuel Cell Power System for Submersible Applications

To address the Navy's need for long endurance power sources for undersea weapons, FuelCell Energy, Inc. evaluated a fuel cell based hybrid propulsion system concept. This effort was supported by the Office of Naval Research (ONR) under an STTR award titled "Hybrid Propulsion System" (N00014-06-C-0406). The system comprises a high power steam turbine section, a low power solid oxide fuel cell (SOFC) section, shared fuel and oxidant supplies, and a common drive mechanism (Figure 1). The fuel cell provides both the low speed motive power via an electric motor and the housekeeping power for guidance & control, sensors, and transmitters. The high power system activates only when high speeds are required during target prosecution.



**Figure 1:** Schematic of the conceptual hybrid system:  
Both propulsion systems share the same reactants and drive train.

The hybrid propulsion system was designed to perform both autonomous surveillance and target prosecution for a combination of high power and low power demands. Alternative sources of fuel and oxygen were investigated. Because undersea weapons are constrained in both their gravimetric and volumetric payloads, trade studies were performed. The hybrid system for the undersea weapons has been designed to accommodate different power requirements consisting of both the high power for target prosecution and low power for long-term surveillance.

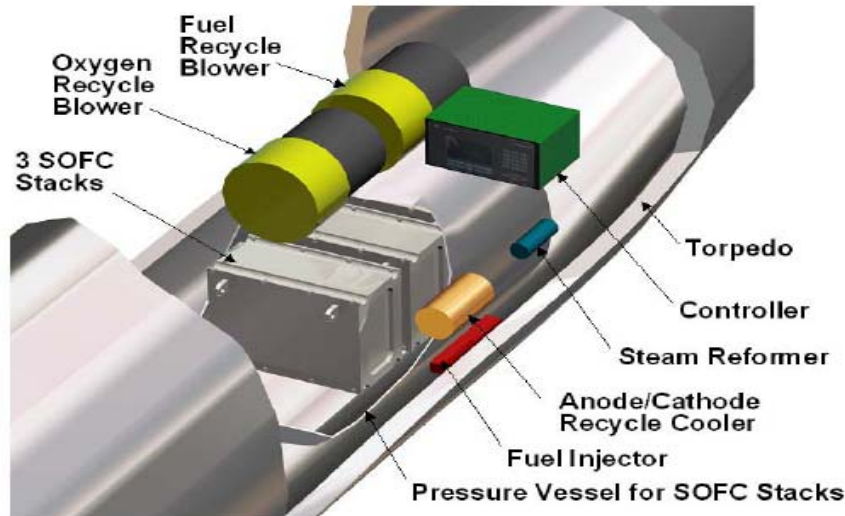
As an alternative to JP-5 marine fuel, use of methanol as a fuel was studied. Methanol has reduced fuel pre-processing requirements but only half the volumetric energy density of JP-5. Options for oxidant delivery and source of oxygen were also considered including pressurized oxygen and lithium perchlorate. A solid lithium-perchlorate based oxygen generator has the potential to increase the oxygen storage density by a factor of five compared to gaseous oxygen stored at 6000 psi.

In multidisciplinary design optimization studies, three oxygen storage options (high pressure gas at 3000 psi and 600 psi, and solid lithium-perchlorate) and two hybrid designs (dual turbine, SOFC) were analyzed. The most attractive design was shown to be based on JP-5 fuel, a lithium-perchlorate oxygen source, using an SOFC for the low power requirement, and a steam turbine for meeting high power demand.

The evaluated SOFC based hybrid systems offer more than a two-fold increase in electrical efficiency compared to the conventional steam turbine based systems. The reduced usage of both fuel and oxygen



provide a significantly longer endurance capability, as much as 20 times compared to conventional propulsion systems.. The long endurance is made possible by the SOFC system's high electrical efficiency and small size. Conceptual system component layout in a torpedo tube is shown in Figure 2.



**Figure 2:** Close-up of the conceptual SOFC system inside the torpedo shell.

The conceptual studies showed that an effective hybrid propulsion system consists of two parallel systems operating on the same fuel and oxidizer sources:

- A high power level open combustion/closed Rankine (water based) system fueled by combustion of JP-5 liquid fuel and  $\text{LiClO}_4$  based  $\text{O}_2$  oxidizer, which provides propulsor shaft power.
- A low power system driven by an SOFC fuel cell, fueled by reformed JP-5 liquid fuel and ( $\text{LiClO}_4$  based)  $\text{O}_2$  in-turn driving an electric motor suitable for propulsion, possibly by a geared connection to the propulsor shaft.

**Project Partners:**

Office of Naval Research (ONR)  
Naval Undersea Warfare Center (NUWC)  
Barber Nichols, Inc., Arvada, CO  
The Pennsylvania State University, State College, PA  
Versa Power Systems, Calgary, Alberta Canada

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