

# QynCap Energy Storage Device for Airborne Directed Energy Weapons

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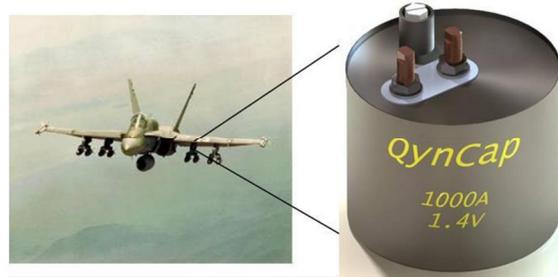
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**Command: NAVAIR**

**Topic: N08-130 Pulse Power Electrical Energy Storage Device**

## PROBLEM STATEMENT

The Navy has various programs and proposed upgrades (Joint Strike Fighter (JSF) and others) that hold high promise in providing revolutionary gains in warfighting capability. These programs will place extraordinary demands on electrical power and energy storage devices, especially for pulsed power applications. Current batteries are not suitable for many of these applications; therefore, an advanced pulsed power energy storage device is needed for increased functionality on-board Naval aircraft.

## WHO CAN BENEFIT?

A pulsed power energy storage device will enable airborne directed energy weapons with a smaller and lighter footprint. Additionally, it will offer increased functionality to the all-electric aircraft, including higher peak power and longer power system lifetime.

One organization that could benefit is the Directed Energy Program at the Office of Naval Research (Code 35, Division 352), which has commenced development and implementation of the Maritime Laser Demonstration (MLD) Program.<sup>1</sup>

The Naval Directed Energy and Electric Weapon Systems program office's (PMS 405) mission is to transition technology from the laboratory to prototype/advanced development/test for operational development and use and will manage development of Directed Energy and Electric Weapon Systems onboard future naval surface ships that incorporate: Weapons Grade High Energy Lasers, Free Electron Lasers (Megawatt class),

<sup>1</sup> <http://www.onr.navy.mil/Science-Technology/Departments/Code-35/All-Programs/air-warfare-352/Directed-Energy.aspx>

Electromagnetic Rail Gun (EMRG) Weapon System, High Power Microwave Weapon/Sensor Systems, and other systems/capabilities.<sup>2</sup>

Other programs/facilities of interest include the Airborne Laser Test Bed (ALTB), the Joint High Power Solid State Laser (JHPSSL) program, the Army's High Energy Laser System Test Facility (HELSTF), Tactical High Energy Laser (THEL), Solid State Laser Testbed Experiment (SSLTE) and the U.S. Navy's Free Electron Laser (FEL) weapon system.<sup>3</sup>

Other potential defense-related applications include:

- Electric actuators in fixed-wing, all electric aircraft
- Vehicle engine starting
- Active suspension in electric or hybrid-electric vehicles
- Regenerative braking energy capture in electric or hybrid-electric vehicles
- Peak power for radar and radio communications
- Bridge power for back-up generators
- Unmanned Aerial Vehicle (UAV) communications and weapons
- Voltage hold-up during peak currents
- Electromagnetic Aircraft Launch System (EMALS)

## BASELINE TECHNOLOGY

Lead-acid and Nickel-Cadmium (NiCd) batteries are currently used for electrical energy storage onboard Naval aircraft. Because these battery technologies have relatively low power densities (75-200 W/kg), they must be oversized to meet high pulsed power loads, adding extra weight and occupying more space on the aircraft. Also, lead-acid batteries can only be charged and discharged 200-400 times, so frequent replacement is required. NiCd batteries have higher cycle life (2000), but many pulsed power applications require tens of thousands of charge/discharge cycles. Operating temperature is another disadvantage of both lead-acid and NiCd batteries. Typically, they must be housed in a climate-controlled location on the aircraft to ensure the temperature stays above -20°C. The primary advantages of both technologies are maturity and relatively low unit cost, ~\$100/kWh for lead-acid and ~\$300/kWh for NiCd.

Lithium-ion (Li-ion) batteries are the heir-apparent to lead-acid and NiCd batteries in many aircraft applications. They are available in several different chemistries and can be classified as either *high power* or *high energy* batteries. High power Li-ion batteries have high power density (1500 W/kg), moderate energy density (70 Wh/kg), and reasonable cycle life (2000). High energy Li-ion batteries have moderate power density (300 W/kg) density, high energy density (150 Wh/kg), and reasonable cycle life (1200). However,

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<sup>2</sup> [www.dtic.mil/descriptivesum/Y2010/Navy/0603925N.pdf](http://www.dtic.mil/descriptivesum/Y2010/Navy/0603925N.pdf)

<sup>3</sup> [http://www.militaryaerospace.com/index/display/article-display/0827194684/articles/military-aerospace-electronics/exclusive-content/2010/5/laser-weapons\\_development.html](http://www.militaryaerospace.com/index/display/article-display/0827194684/articles/military-aerospace-electronics/exclusive-content/2010/5/laser-weapons_development.html)

both types of Li-ion batteries are very costly (\$1000-\$2000/kWh),<sup>4</sup> do not operate much below -20°C, and have not generally been qualified for use onboard aircraft. Also, there are significant safety concerns with Li-ion batteries, due to well-documented internal shorting and thermal runaway issues.

### TECHNOLOGY DESCRIPTION

Our technology, the QynCap, is a novel electrochemical capacitor (aka ultracapacitor or supercapacitor). Compared with capacitors, which store charge in the electric field between two plates, ultracapacitors utilize high surface area electrode materials in conjunction with an electrolyte to store orders of magnitude more charge in the pores of the electrodes. Because of the use of these high surface area materials, ultracapacitors can store above 1 Wh/kg while capacitors may reach 0.01 Wh/kg. However, because they have no chemical reactions (unlike batteries) ultracapacitors maintain the good pulsed power performance that capacitors are known for, during discharge *and* charge. They can also be cycled more than 100,000 times. The QynCap ultracapacitor will theoretically store more charge (and therefore energy) per weight and volume than traditional ultracapacitors, approaching the energy density of lead-acid batteries. It will also deliver higher powers and operate over a wider temperature range than traditional ultracapacitors and batteries. For pulsed power applications, the high power density of the QynCap means that it can provide the necessary power at a fraction of the size and weight of any of the baseline battery technologies.



**Figure 1: QynCap prototype, can is 4.5" diameter × 4.75" high**

**Table 1: FAB table for the QynCap ultracapacitor.**

<i><b>Feature</b></i>	<i><b>Advantage</b></i>	<i><b>Benefit</b></i>
High power density (>5000 W/kg)	Smaller size and weight	Frees up space on platform
Wide operating temp range (-55°C to 65°C)	Operates better at cold temperatures than competitors	Increased power performance at extreme temperatures
High cycle life (>100,000)	Can be recharged many more times than batteries	Reduces frequency of replacement and maintenance required
Aqueous electrolyte	Non-flammable	Increased safety
Fast recharge time	Full recharge in a fraction of the time it takes a battery to recharge	QynCap is ready for re-use very quickly

<sup>4</sup> Peterson, J. (2009, Apr. 6). Lithium-ion Batteries: 9 Years of Price Stagnation. *Seeking Alpha*. Retrieved from <http://seekingalpha.com>

**Table 2: Comparison to baseline.**

	<i><b>QynCap</b></i>	<i><b>Traditional Ultracap.</b></i>	<i><b>Lead-acid Battery</b></i>	<i><b>NiCd Battery</b></i>	<i><b>High Power Li-ion Battery</b></i>
Power Density (W/kg)	5000	3000	100	200	1500
Energy Density (Wh/kg)	10	5	30	50	70
Cycle Life	100,000	1,000,000	400	2000	2000
Operating Temp (°C)	-55 to 65	-40 to 65	-20 to 65	-40 to 60	-20 to 65

For many applications, the QynCap is best used in a hybrid configuration with a very high energy density battery, such as a high energy Li-ion battery. This type of Energy Storage System (ESS) allows the designer to independently optimize the QynCap for pulsed power loads, while the battery supplies power for the continuous loads and QynCap charging. Depending on the load details, overall system energy density and power density can be minimized with a QynCap-based hybrid ESS compared to a stand-alone Li-ion battery. These applications could be directed energy weapons, re-gen braking in hybrid electric vehicles, and SmartGrid backup energy storage. Other applications are better suited to stand-alone QynCaps. With vehicle starting, for instance, a QynCap-only solution will last the life of the vehicle and offer improved cold start capability.

### **CURRENT STATE OF DEVELOPMENT**

The technology is currently at Technology Readiness Level (TRL) 3, scaled-down experimental cells have been fabricated and proof-of-principle demonstrated. The first full-scale operational prototypes were recently completed; delivery to NAVAIR for testing occurred in Oct 2010. A second round of prototypes will be delivered to NAVAIR in Feb 2011. A 14V multi-cell module, complete with active cell balancing and temperature sensing, will be fabricated and delivered to NAVAIR in July 2011.

### **REFERENCES**

Multi-cell modules containing prismatic QynCap cells were delivered under contract to the Army/Tank and Automotive Research, Development, and Engineering Center (TARDEC) in 2009. Test results demonstrated high internal resistance, which led directly to the spirally-wound cell design under development here.

Technical Point of Contact: Energy Storage Team Leader, (586) 282-5503

## WHEN THE TECHNOLOGY WILL BE READY FOR USE

By the end of this Phase II SBIR Basic Effort (July 2011), the spirally-wound QynCap will be at TRL 4. In order to move from TRL 4 to 7 over the subsequent 12-18 months, additional funding (amount depending on the target program) is required to accomplish the necessary mechanical and environmental testing. By 2013, the QynCap will be ready for flight qualification to move to TRL 8 and 9.

## ABOUT THE COMPANY

Qynergy Corporation is a privately-held company that was founded in 2001 for the purpose of developing cutting-edge energy and power solutions. Qynergy originally licensed technology from Sandia National Laboratories and the University of New Mexico for development of their betavoltaic power cells (QynCells). Qynergy's cost accounting system is approved by the Defense Contract Audit Agency (DCAA), which allows us to compete and win federal government contracts and grants.

Qynergy is successfully blending private and public funding to create a family of products that provide portable power capabilities that do not exist in current battery and energy storage systems. Using its proprietary QynCell technology, Qynergy has created compact, high energy density power cells that use radiation-hard semiconductor materials to harness the power emitted by radioisotopes. This technology is analogous to solar cell conversion of light to electric power. At the other end of the spectrum is the QynCap, an ultracapacitor technology developed specifically for high pulsed power applications. Qynergy has most recently worked directly with the Army/TARDEC to develop a North American Treaty Organization (NATO) 6T QynCap for ground vehicle engine starting. Qynergy also has expertise in the radiation detection arena, having ongoing projects in both neutron detection and neutron generation.

Qynergy's expertise in ultracapacitors, nuclear engineering, material science, semiconductor engineering and microelectronic systems enables us to develop custom power systems for defense, intelligence, homeland security and commercial customers. 40 percent of our staff at Qynergy has advanced degrees in fields ranging from electrical engineering to material science and business. The leadership team assembled at Qynergy is market-driven and has extensive experience in rapidly identifying opportunities and moving products to the marketplace. Qynergy intends to utilize this experience in bringing the QynCap to market.

The Qynergy facility, located in Albuquerque, NM, has 1,185 square feet of laboratory space specifically designed for engineering, prototype manufacturing, and testing. Qynergy has all of the tools necessary for fabricating ultracapacitors, including: a semi-automated electrode coater, a semi-automated spiral winder, a press, a ball-mill, a 5"× 8" automated rolling mill, a mixer, an air shear, a micro-pulse arc welder, a convection drying oven, and a variety of glassware for wet chemistry. For testing, Qynergy has a Maccor fully automated battery/ultracapacitor cycling system that consists of sixteen

5V/15A channels, which can be connected in series or parallel (eight channels at a time). Another sixteen 12V/5A channels can be used for three-electrode cell measurements, temperature monitoring, and auxiliary voltage experiments. Qynergy also has two programmable Tenney environmental chambers for testing between -70°C and 200°C, as well as four Quincy Lab benchtop ovens for testing between 40°C and 220°C. Qynergy has a full range of benchtop equipment for electric circuit design, test and measurement, including: a variety of Keithley and Agilent sourcemeters and data acquisition units, LeCroy oscilloscopes, and DC power supplies.