FastCap® Ultracapacitors

Structural Ultracapacitor Energy Storage

STRUCTURAL ULTRACAPACITORS ENHANCE ENERGY AND POWER DENSITY IN SPACE CONSTRAINED DESIGNS

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INTRODUCTION

The concept of structural energy storage seeks to synergistically combine the mechanical, load-bearing qualities of chassis infrastructures with the electrical, power-delivering capabilities of contemporary energy storage solutions. Capacitor sizes and shapes are tailored for space constrained and unusual shapes where conventional cylindrical or prismatic solutions are difficult to integrate. Applications target either a reduction in system size or an augmentation in system power and energy. Strong candidates for this technology include:

- Satellites (CubeSats, NanoSats)
- Unmanned Aerial Vehicles (UAVs)
- Robotic Platforms
- Cargo Modules
- Micro-sensors
- Missile Systems
- Underwater Vehicles
- Light Military Vehicles
- Electric Vehicles
- Electric Motorcycles, Scooters
- Motor Housings
- Integrated Renewable Storage
- Race Cars and Motorcycles
- Small Consumer Electronics
- Battery Chargers
- Hybrid Battery Systems

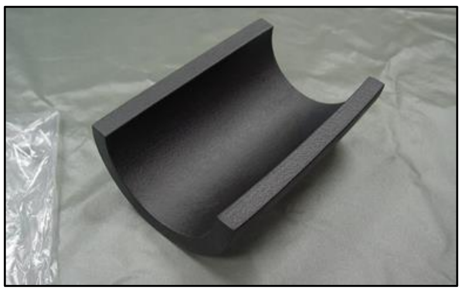

Figure 1 Conventional storage fits well into rectangular designs. Structural storage enabled curved and cylindrical volume efficiency

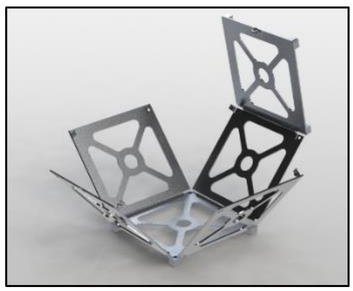

Figure 2 Frames can be replaced with structural storage elements resulting in reduced mass and volume

Figure 3 Shapes vary with application with thickness down to 1/8"

The integration of mechanical and electrical subsystems is projected to increase overall energy and power densities and ultimately result in extended runtimes and enhanced power. In the case of miniaturization, replacing electrically inactive mechanical subassemblies with structural energy storage will enable the adoption of smaller energy storage subsystems with the possibility of eliminating these subsystems entirely as they are absorbed into the body of the vehicle. Further benefits may be realized in the form of system weight reduction if the appropriate structural energy storage substitution weighs less than the original inactive mechanical support. In the case of power and energy enhancement, structural energy storage may be incorporated to complement pre-existing energy storage solutions to increase overall vehicle performance.

AUTOMOTIVE

Designs currently underway seek to reduce automobile weight while enhancing power and energy to improve performance and extend range. **Figure 4**[1] illustrates the replacement of inactive vehicle materials such as car body paneling to address these performance metrics. This reconfiguration can provide additional power and energy to the electric powertrain as well as auxiliary electrical systems. As indicated, this reconfiguration may also lower the overall weight of the vehicle through replacement of some of the steel paneling with composite materials.

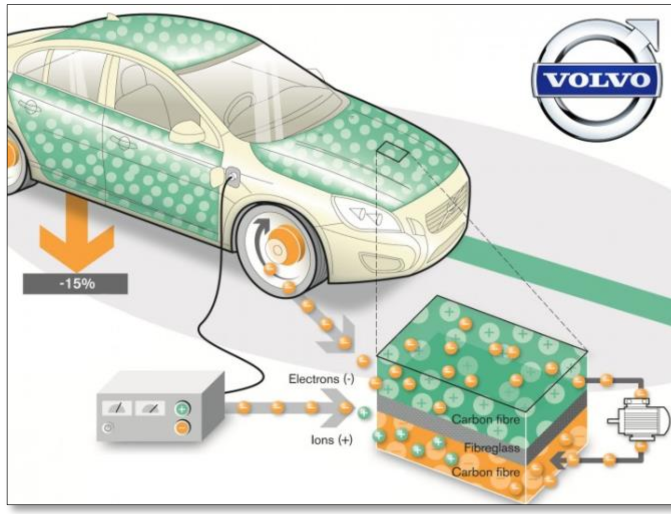

Figure 4 Automotive structural energy storage concept

Due to the logistics regarding servicing car body paneling, incorporation of the energy storage into the physical structure of the vehicle necessitates both a mechanically and electrically durable solution. From an electrical perspective, the structural energy storage should exhibit a long cycle life, accommodating a large number of charges and discharges without appreciable degradation.

Ultracapacitors are a suitable technology that can address the power requirements associated with the automotive environment. An alternative energy storage solution is Lithium-ion. Although Lithium chemistries tend to have a much higher energy density than ultracapacitors, their cycle lives are generally much shorter. Lithium-ion batteries have a typical cycle life on the order of 500 cycles, whereas ultracapacitors have a cycle life on the order of 500,000 cycles. As such, Lithium-ion technology would be a less attractive solution for structural energy storage in its current state.

Ultracapacitor Structural Storage	**Lithium Ion Structural Storage**
Long Life Cycle (>1M cycle lifetime)	Short Life Cycle (500-2000 cycles)
High Power	High Energy
Stable, High Safety Factor	Volatile, Low Safety Factor

Table 1 lists several ultracapacitor manufacturers and compares their respective technological level with respect to a common form factor.

Parameter	Nanoramic	Ioxus	Maxwell
Maximum Cell Voltage (V)	3.0	2.7	2.5
Cell ESR (mΩ)	1	2.5	3.2
Cell Capacitance (F)	460	400	350

Table 1 Comparison of ultracapacitor technologies

[1] http://arpa-e.energy.gov/sites/default/files/documents/files/CSESS%20Asp.pdf

AEROSPACE

Beyond terrestrial devices, structural energy storage is also finding applications in the aerospace sector. Satellites are a prime example of space-constrained machines that greatly rely on both volumetric and gravimetric electrical efficiency. A payload's cost per unit weight is a metric largely driving satellite and rocket design. Small form factor satellites such as the one depicted in **Figure** [2] can be retrofitted with structural energy storage to reduce weight and, in turn, the cost of deployment.

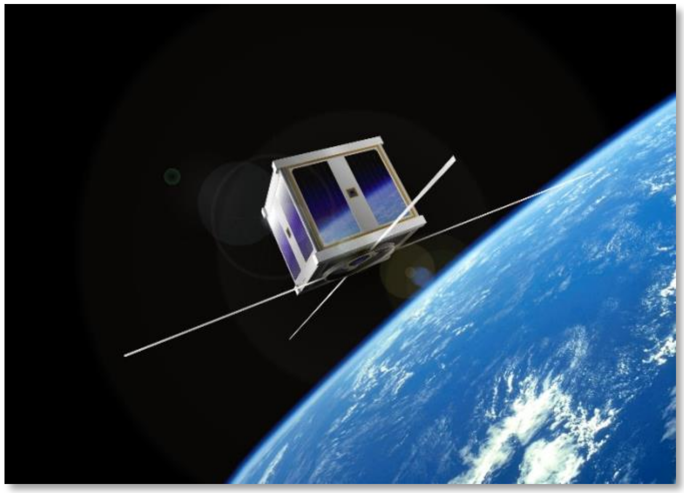

Figure 5 Artist rendering of a CubeSat

Similar to the automotive application of structural energy storage, this technology is required to be rugged, reliable, and capable of withstanding environments such as those encountered in Low Earth Orbit (LEO) where temperatures can reach as high as 125 C.[3] In addition to the thermal requirements of aerospace energy storage solutions, there are additional mechanical constraints that these systems must satisfy such as resistance to the shock and vibration experienced during launch and deployment. **Table 2** lists several ultracapacitor manufacturers and compares their respective environmental specifications.

Parameter	Nanoramic	Maxwell
Maximum Operating Temperature (C)	150	70
Vibration Amplitude (Grms)	40	5.9
Shock Amplitude (G)	500	100

Table 2 Comparison of ultracapacitor technologies

STRUCTURAL ULTRACAPACITOR

We have seen that structural energy storage can benefit both the automotive and aerospace industries. Leveraging their expertise in the design of environmentally ruggedized ultracapacitor energy storage, Nanoramic is developing structural ultracapacitor systems targeted at the automotive and aerospace space sectors. The robust nature of the design will also lend itself to future implementation in defense applications ranging from body armor to UAVs. The structural ultracapacitor is poised to increase performance and efficiencies in space constrained environments.

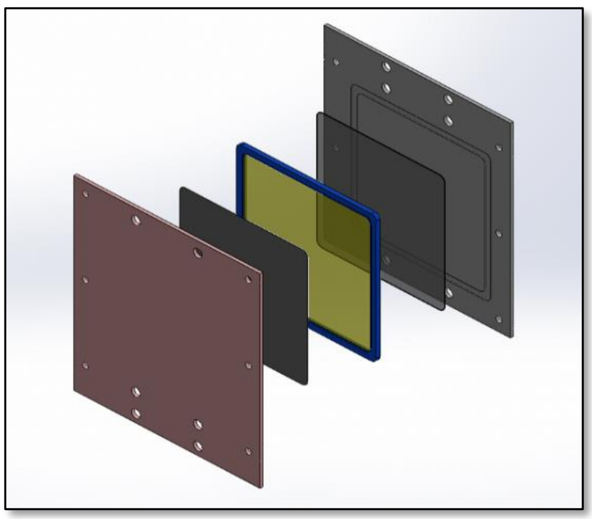

Figure 2 Conceptual structural ultracapacitor

[2] http://www.space.aau.dk/

[3] https://nepp.nasa.gov/files/11004/Environmental%20Testing%20Survey.doc