CMSE 2025: Planar Magnetics And Supercapacitors Offer Advances For Space

by David G. Morrison, Editor, How2Power.com

The Components for Military & Space Electronics (CMSE) conference addresses developments in components, especially passives, as well as packaging & interconnects, and includes talks on reliability. In recent years, heterogenous integration (HI) has become a popular topic here and at other conferences. One definition of HI is "a device built using both electronic and non-electronic materials/parts,"[1] while others commonly use the term to describe the combination of different semiconductor materials at the wafer level[1] or in a system-in-package concept.[2] While the CMSE talks on HI have not focused on power electronics for the most part, others are discussing it in this context, particularly with respect to processor power.[3,4]

In recent years, sourcing challenges have also been prominent at CMSE and there have been talks on government programs to bolster the microelectronics supply chain as well as the workforce. With regard to component availability, the role of COTS parts in military and space applications only seems to grow over time and COTS is a regular topic of discussion at CMSE. For example, at this year's CMSE, which was held October 29-May 1st at the Renaissance Los Angeles Airport Hotel, Larry Harzstark of the Aerospace Corporation presented a plenary titled, "Electronic Parts Standards: Past, Present and Future."

In his talk Harzstark observed that "military/space parts are generations behind the commercial parts industry," so we "need to develop guidelines and practices for use of commercial technologies". He added that "various government and industry teams are working to develop information as to how to best use commercial technologies".

A copy of Harzstark's very informative presentation with its history of Mil standards for electronic components and discussion of chip manufacturing as it relates to these standards is available online.[5] Most timely is its description of the developing standard, "MIL-PRF-ATM (Advanced Technology Microcircuit), which is intended to bring heterogeneous integrated (HI) components into the military specification (QML) arena."

At the recent CMSE 2025, the attention to developments in capacitors and magnetics continued, with two topics getting special attention in the program—planar magnetics and supercapacitors. Both areas are compelling for military and space applications because of the requirements for components that can handle high power in compact form factors.

While planars and supercaps are not new to these application areas, some designers may not be familiar with their benefits, and the new materials and design styles that are emerging to further enhance their performance. This article will present highlights from two talks on planar magnetics and two talks on supercaps (aka ultracaps or electric double layer capacitors) that address the current advantages and recent developments in these technologies relevant to space and military applications.

Planar Magnetics Offer Performance And Reliability

Planar magnetics have been around for decades. With their smaller size and weight, higher efficiency, better manufacturability, and more repeatable characteristics versus wound power transformers and inductors, planar magnetic components are especially attractive for military and space applications. This year, two of the presentations at CMSE discussed the suitability and advantages of these components in the high-reliability space and military applications.

In his talk, Jim Marinos of Payton Planar, a manufacturer of custom planar devices, explained "Why Planar Magnetics are Ideal for Harsh Environments".[6] In addition to the advantages noted above, Marinos cited some additional characteristics beneficial for space.

One is their suitability for conduction cooling. Another is the existance of established screening requirements for planar magnetics in EEE INST-002, Mil-Std-981 and Mil-STD-1580

Additionally, planars have an established track record in space. As Marinos noted, his company has produced over 300 magnetic designs for space applications. These include designs that have passed partial discharge testing up to 20 KVrms with detection rates to 1 pC.

Elaborating on their simple construction, Marinos explained that they are built in layers, which makes construction reliable and repeatable. This in turn makes it easier to control electrical parameters such as leakage and capacitance than in a wound component. As an example, he showed a breakout of a planar transformer developed for space (Fig. 1). Despite its multiple primary and secondary windings, its construction is relatively simple with few components.

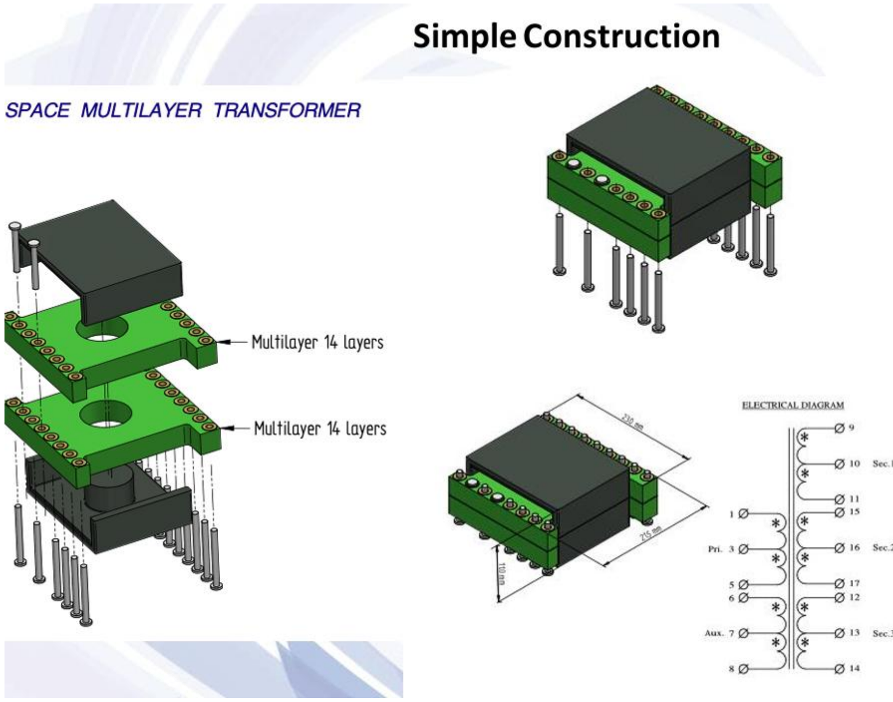

Fig. 1. Planar transformers feature simple construction.

With that as background, Marinos' explored issues that determine component reliability. Managing thermals is key. The magnetic must be designed to a maximum internal hotspot specification with the required cooling to stay within that spec. This will ultimately determine MTBF in the targeted environment. Both cooling and derating will be required to achieve the desired MTBF as calculated by the equation described in Fig. 2.

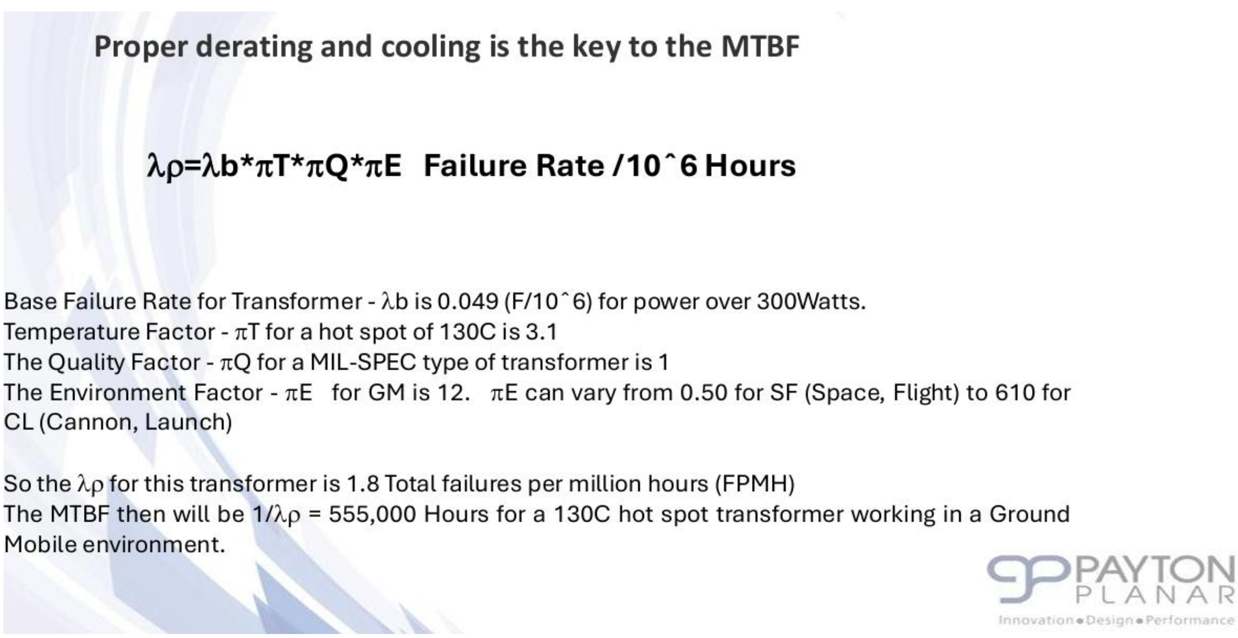

Fig. 2. Calculating MTBF for a planar transformer.

Towards the end of his presentation, Marinos noted that there are a variety of factors that contribute to product lifetime for planar magnetics in harsh environments. These include:

- Loss of inductance over time
- Failures of multilayer boards (laminates and prepregs due to Tg, Td, thermal and moisture effects)
- Failures of ferrite cores with MnZn
- Failures of ferrite glue
- Partial discharges.

Marinos also discussed some of the trends in requirements for capacitance and leakage inductance. As he observed "While in the past hard switching topologies inclined towards minimizing leakage inductance, today's more common LLC and DAB topologies tend to require specific leakage inductance values and minimizing of primary to secondary capacitance, and distributed capacitance." In terms of controlling leakage inductance by design, he noted that "leakage inductance can be achieved in multiple ways by using integrated or separate components, while capacitance requires tight control of winding type and insulation materials." He added that "the high repeatability [of planar magnetic components] is a result of keeping the parasitics controlled by design."

Obviously behind these broad guidelines, there are many details to be managed requiring experience with the various materials and manufacturing processes used to build the components.

Marinos' presentation also included examples of how a planar transformer design is tested to locate and fix thermal problems (Fig. 3), and how a design is simulated in Ansys to check parameters such as flux distribution, thermals, impedance and risk of PD (Fig. 4).

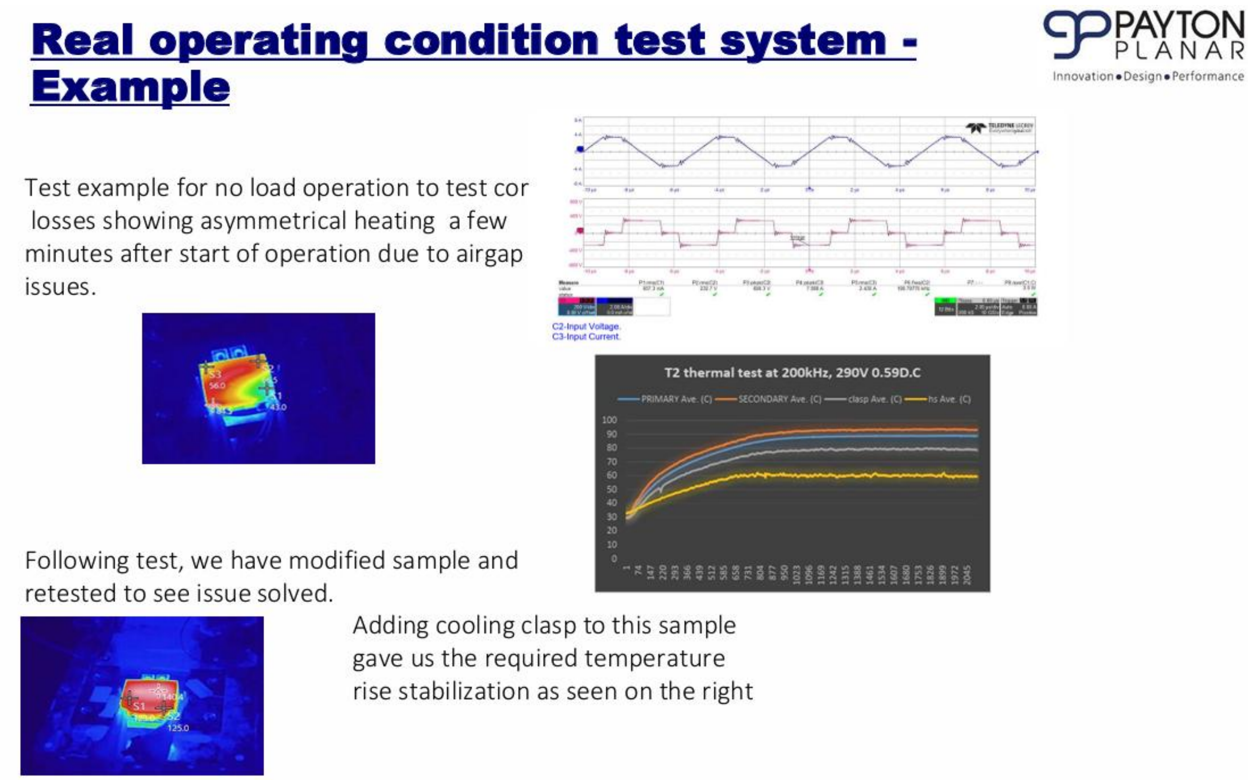

Fig. 3. Thermal testing of a planar magnetic sample from Payton Planar.

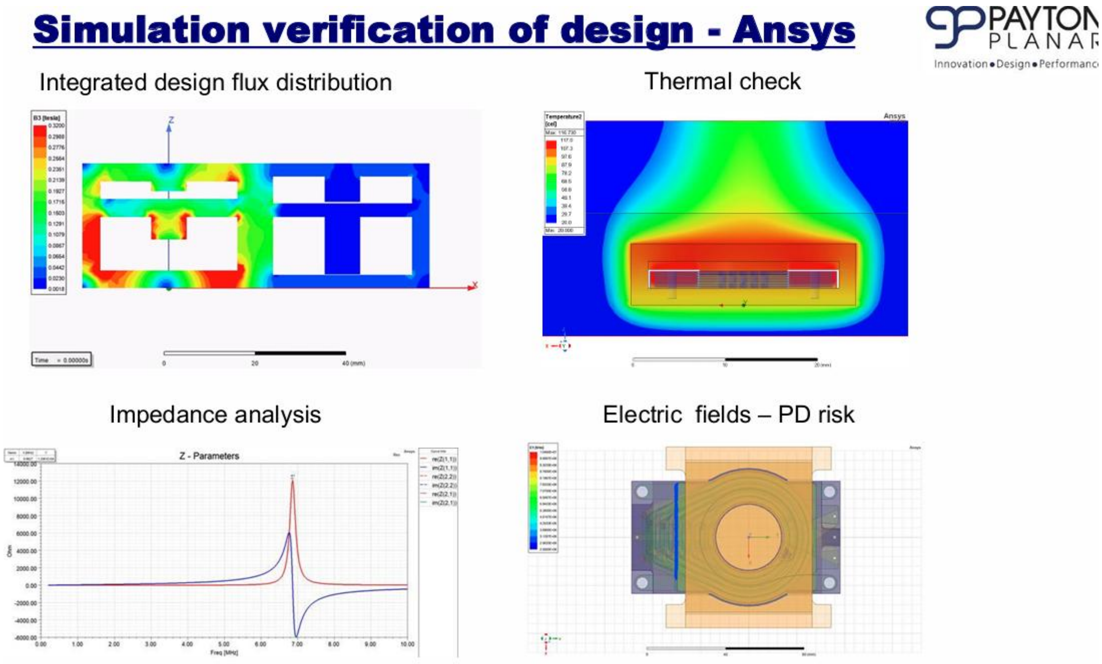

Fig. 4. Simulating a planar magnetic design in Ansys tools such as Maxwell.

He also noted Mil-Standard requirements for visual and radiographic inspection, and material analysis (to avoid prohibited materials). Tables and a flow chart of a qualification plan for planar magnetics in his presentation revealed the numerous mechanical and electrical tests required to meet Mil-Std-981 and Mil-STD-1580. Example test setups and results for shock and vibration tests as well as life tests under load were shown. For more information see the presentation[6] or contact Jim Marinos.

While Marinos' talk discussed the benefits of conventional planar magnetic components in harsh environments such as those in space, and the design considerations to achieve the required reliability, another talk at CMSE 2025 described what can be achieved with a variation on planar magnetic design. In his presentation, Jackson Sonterre of Vishay's Inductors Division explored the "Benefits of a Hybrid Planar Transformer Package".[7] Rather than using pc-board traces that are encapsulated within the board, Vishay's hybrid-style planar employs magnet wire, foils or stampings encapsulated within a mineral-filled epoxy with the option of adding insulators to increase electrical isolation. The slides below highlight the differences in construction (Figs. 5 and 6).

Fig. 5. Comparing Vishay's Hybrid planar with a traditional planar magnetic—different windings and insulating materials are applied in the Hybrid planar.

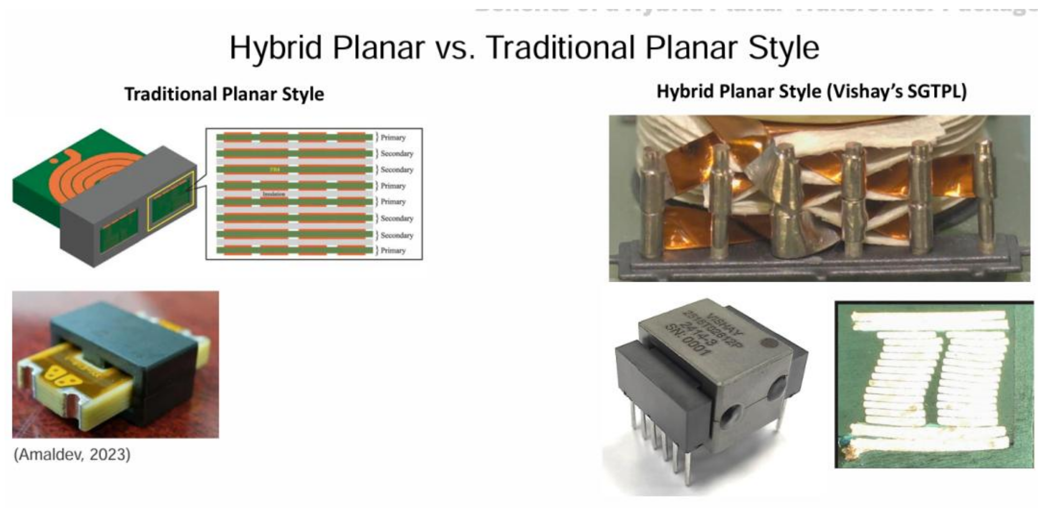

Fig. 6. Comparing Vishay's Hybrid planar with a traditional planar magnetic—cross sectional views.

According to Sonterre, the company's Hybrid planars offer a number of benefits over pc-board style planars. First, they afford higher copper fill percentages, which leads to lower winding resistance and higher efficiency. The components are also more easily customized without changing a component footprint or the pc board to which its mounted.

There's also greater flexibility in winding design without the limitations of pc board windings; higher levels of dielectric strength can be achieved and solder joints are easily inspectable prior to encapsulation. Sonterre also noted that certain tradeoffs and failure modes can be avoided such as etchback, solder fill, delamination, and CTE issues with thicker boards.

In his presentation, Sonterre provided information on screening requirements for magnetic components targeting space applications. These referenced Mil-Std-981 and EEE-INST-002, as did the talk by Marinos. They also included ESCC 3201: European Space Components Coordination Generic Specification for Coils, RF and Power, Fixed; MIL-PRF-27: Military Specification for power, audio and high-power pulse transformers and inductors and AEC-Q200.

Additionally, Sonterre's talk included a table of standard space screenings (listing the various tests and inspections) offered by Vishay and a comparison of the relative costs and leadtimes associated with the different offerings (from production screening all the way up to Mil-Std-981 class S, see Fig. 7.)

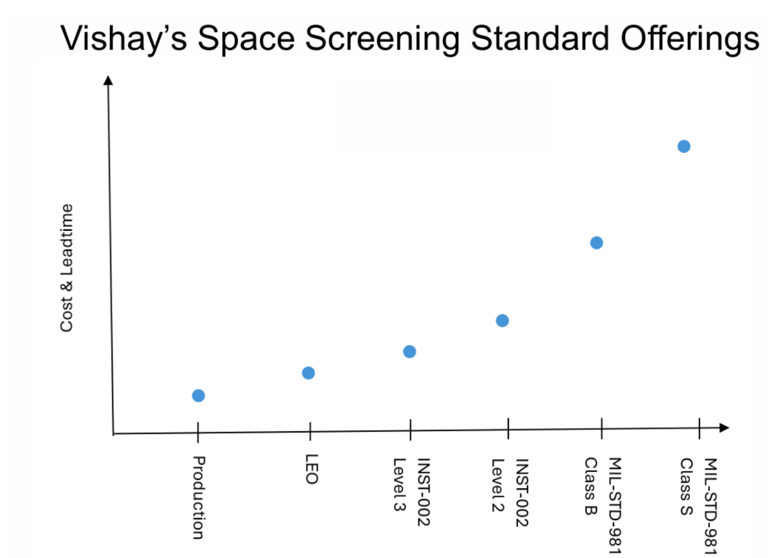

Fig. 7. Vishay offers a range of screening options for its planar devices.

Sonterre prefaced his discussion on Hybrid planars and screening options with an introduction to the subject of magnetics design. That began with a description of the benefits and constraints of transformer design at higher frequencies (200 to 500 kHz) where planars tend to be advantageous and then outlined the importance and impact of core material, core shape, and copper losses covering skin and proximity effects.

While these are the familiar topics in magnetics design, Sonterre also addressed the roles of vacuum impregnation and encapsulation in providing environmental protection, dielectric strength, durability against shock and vibration and the ability to dissipate heat. Another slide devoted to “Benefits of Planar Style Designs” highlighted their lower losses with a graphical comparison of the losses for a planar and a wound transformer illustrating the difference. This background information on magnetics/transformer design provided context for the discussion on Hybrid planars.

For more information, see the presentation,[7] contact Jackson Sonterre.

Supercaps Pursue Better Performance Over Temperature And Higher Energy Density

The benefits of supercapacitors, also known as ultracapacitors or electric double layer capacitors, are well known. They can be used either to augment the performance of batteries, or in some cases replace batteries, because of their unique characteristics. When compared with batteries, supercaps offer higher power density, faster charge and discharge rates, and much longer lifespans being that they are capable of many thousands of charge and discharge cycles.

Supercapacitors are also less affected by temperature, being able to maintain their performance better than batteries at both low and high temperatures. The caveat is that batteries have higher energy density. The graph in Fig. 8 shows the somewhat familiar positioning of batteries versus supercaps.

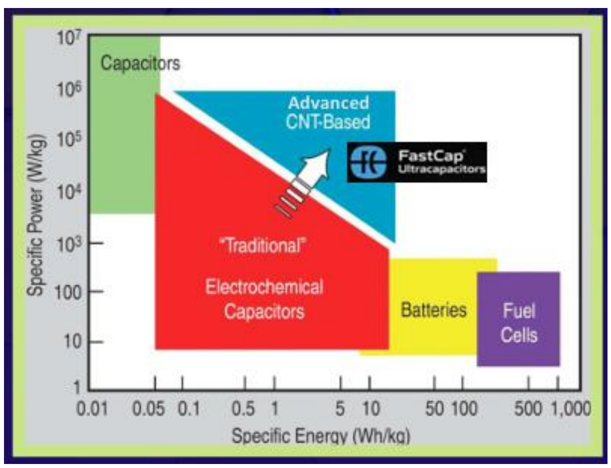

Fig. 8. Comparing power density and energy density for ultracaps versus batteries. (Courtesy of Fastcap)

Fastcap, a company out of Boston has been developing material systems for ultracapacitors that enhance the capabilities of these components to work at extreme temperatures, enabling their use in a wider range of applications. At CMSE 2025, Christopher Deane, chief operating officer of Fastcap, discussed their underlying ultracap technology, and the capabilities and applications for their ultracaps, in his presentation, “Advanced Fastcap Capacitors for Military and Space Electronics And Embedded Solutions.”[8]

As Deane explained, their capacitor designs exploit carbon nanotubes in their electrodes and advanced electrolytes specifically developed for harsh environments. As a result, Fastcap claims the distinction of offering “the only ultracapacitors capable of operating in extreme environments, such as temperatures up to 150°C and under conditions of high shock and vibration and the first reflow solderable chip cap”.

In his talk, Deane discussed the attributes of three of Fastcap’s product families and the applications they benefit. The first of these, the Delta family, features ultracaps in rigid, hermetically sealed cans capable of withstanding shocks up to 1000 G or continuous operation to 20 Grms. They can operate at temps down to -40°C and up to 150°C in their commercial offerings. However, the company has produced prototypes of these components capable of operation to 300°C.

While the commercial devices are available for industrial applications in oil and gas drilling; members of this family may potentially be used in mil aerospace applications as well as stationary energy storage and medical applications. More details on their construction, composition and performance are shown in Figs. 9 and 10.

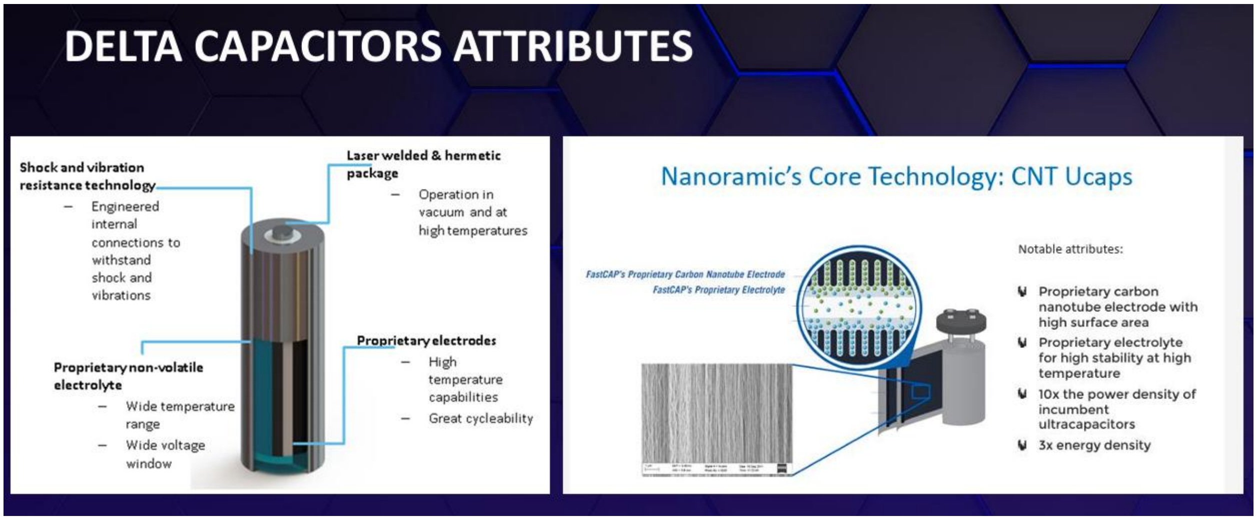

Fig. 9. Fastcap's Delta family supercaps exploit the company's carbon nanotube electrode material and proprietary electrolyte to enable operation at temperature extremes.

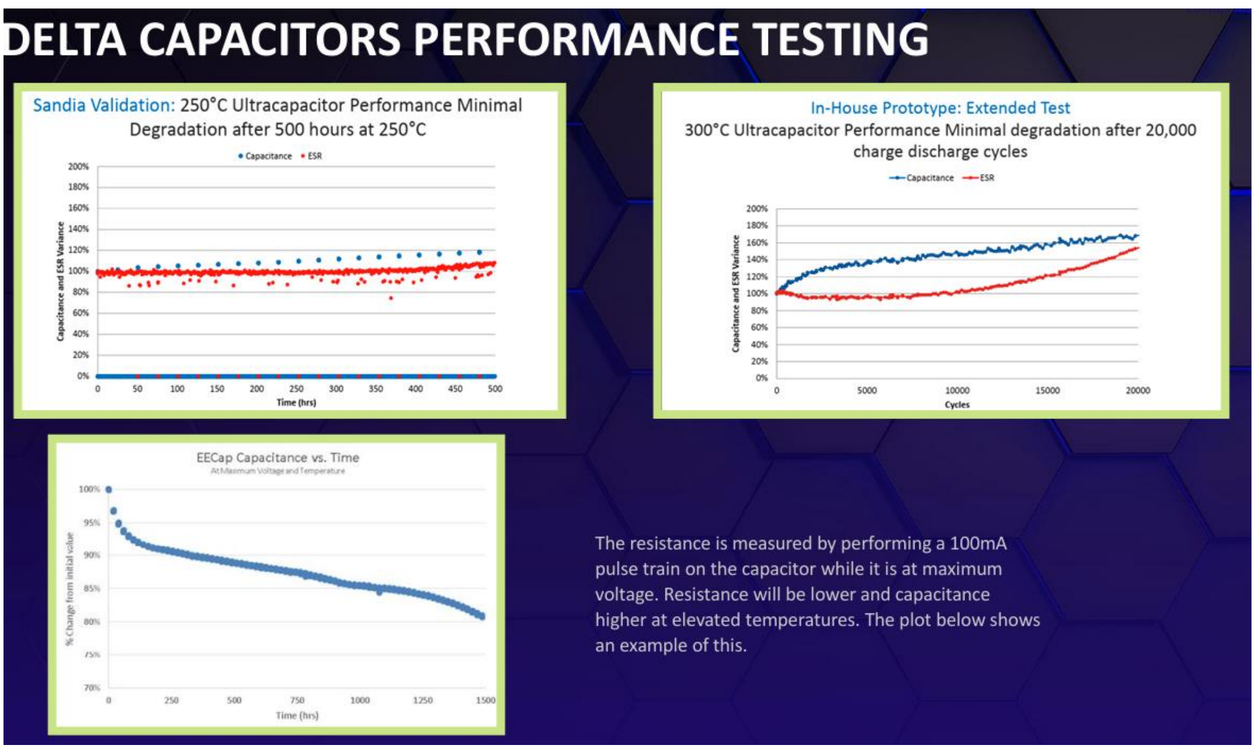

Fig. 10. Fastcap's Delta ultracaps have been shown to exhibit minimal loss of capacitance at high temperature over hundreds of hours of testing.

Meanwhile, the company has also developed a series of ultracaps for extreme low temperature operation. These are members of the Lima family. Also featuring a rigid, hermetically sealed can design, the LIMA EDLC capacitors can operate down to -55°C while still working at temperatures up to 85°C. They can be stored over an even wider range of -65°C to 100°C. The slides below in Figs. 11 and 12 show more details of their performance over temperature. As the data illustrates, these ultracaps were designed to deliver high capacitance and low resistance across the operating temperature range.

Deane noted that these capacitors have become popular in in-flight data recorders where their low-temperature performance eliminates the need for a heating element. The Lima ulltracaps also have other uses in aerospace and defense and transportation or automotive designs. In aerospace, they can provide distributed power buffering at high altitude, or power in-flight sensors.

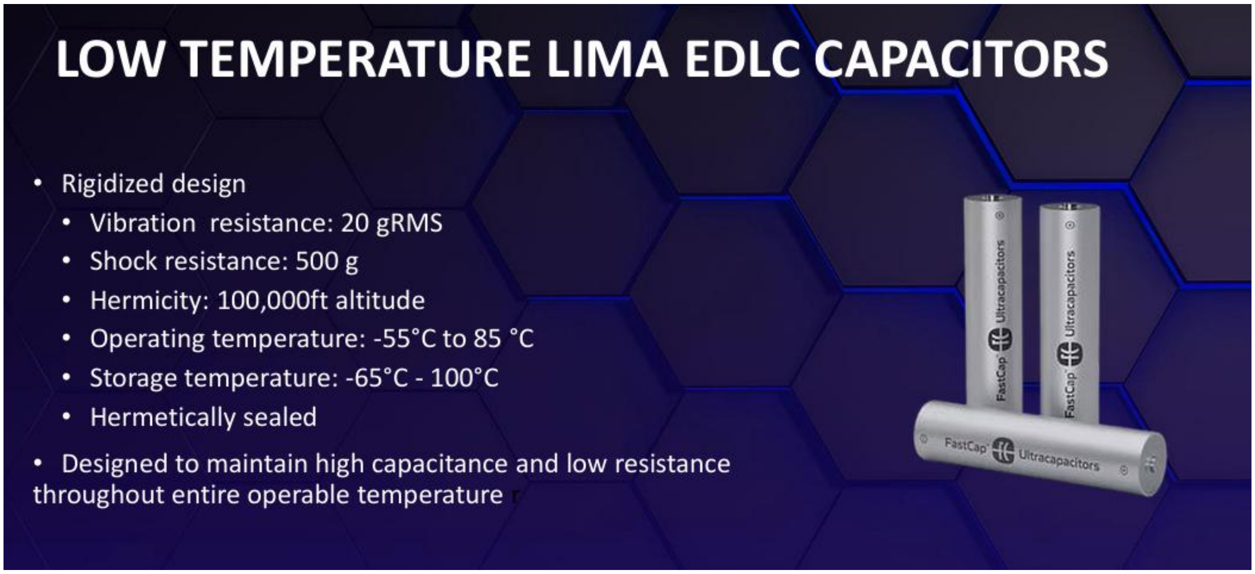

Fig. 11. Fastcap's Lima ultracaps address requirements for performance at very low temperatures.

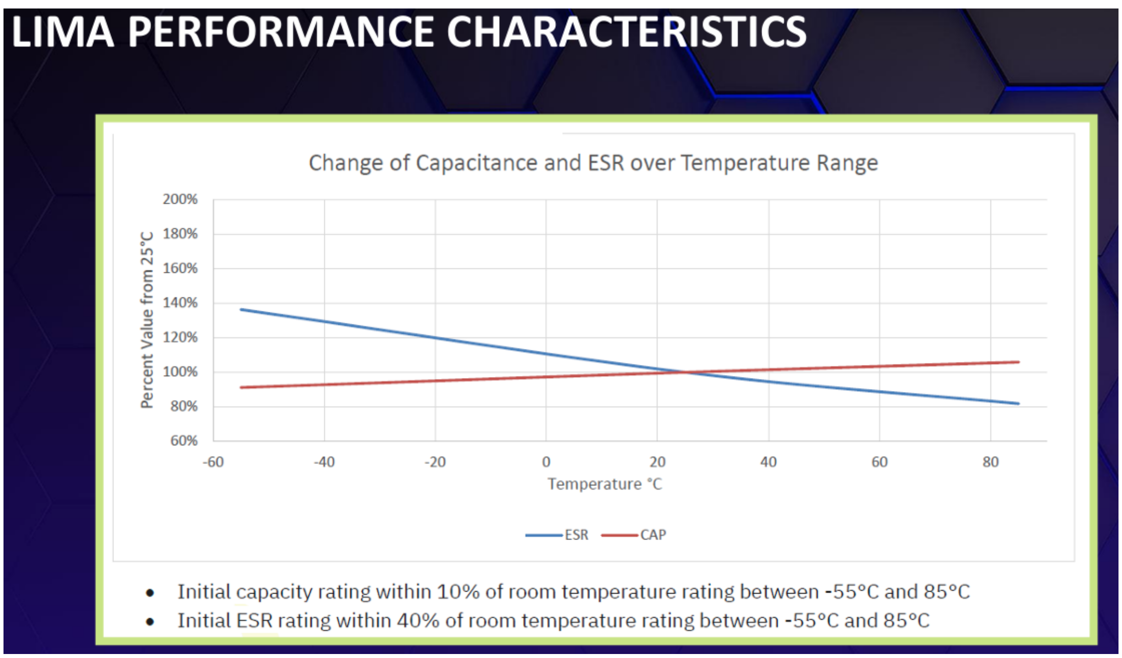

Fig. 12. Capacitance and ESR versus temperature for Fastcap's Lima ultracaps.

Meanwhile, the company's Charlie family offers surface-mountable capacitors (chipcaps) that can withstand a high-temperature solder reflow process. Instead of the metal can, these have a sealed ceramic package suitable for "air sensitive applications". These devices offer improved performance versus other surface-mountable capacitors types.

For example, the Charlie family chipcaps have 10X greater energy density than tantalums, while also offering low ESR and leakage current, and the ability to withstand a high ripple current of 3 A versus 0.4 to 0.5 mA, which is the industry standard according to Fastcap (see Fig. 13.)

These ultracaps target a variety of applications including IoT for military asset management, ground-based power, communication systems, backup power, radars, field medical equipment and edge computing. For more information on these devices, contact [Christopher Deane]() or see the company [website]().

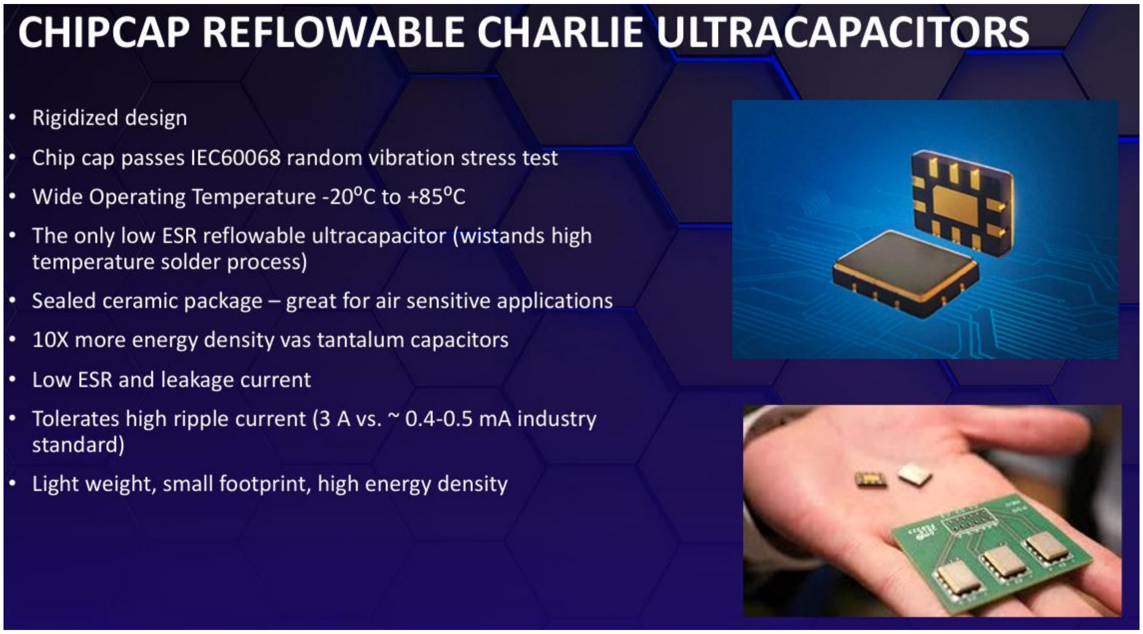

Fig. 13. Fastcap's Charlie family of chipcaps are said to be the only low ESR reflowable ultracapacitors.

Environmental challenges are not the only consideration in military and space applications. In these and other applications, the size and weight constraints motivate further development of ultracapacitors in terms of their power and energy densities. In one of his talks at CMSE 2025, Tomas Zednicek, president and CEO of the European Passive Components Institute, presented information on the "Commercialization of GN3 Graphene Material as the Active Electrode for High Energy Supercapacitors."[9] As Zednicek explained graphene represents a higher-performing alternative to active carbon as an electrode material for supercapacitors.

This material is potentially more conductive with higher power density because of its two-dimensional lattice versus carbon's single layer, which leads to high electron mobility and delocalized electrons with minimal scattering. 2D graphene promises a theoretical maximum capacitance >550 F/g and can be easily paired with other nanomaterials such as carbon nanotubes to create light, high-performance structures. Fig. 14 summarizes these and other features of graphene.

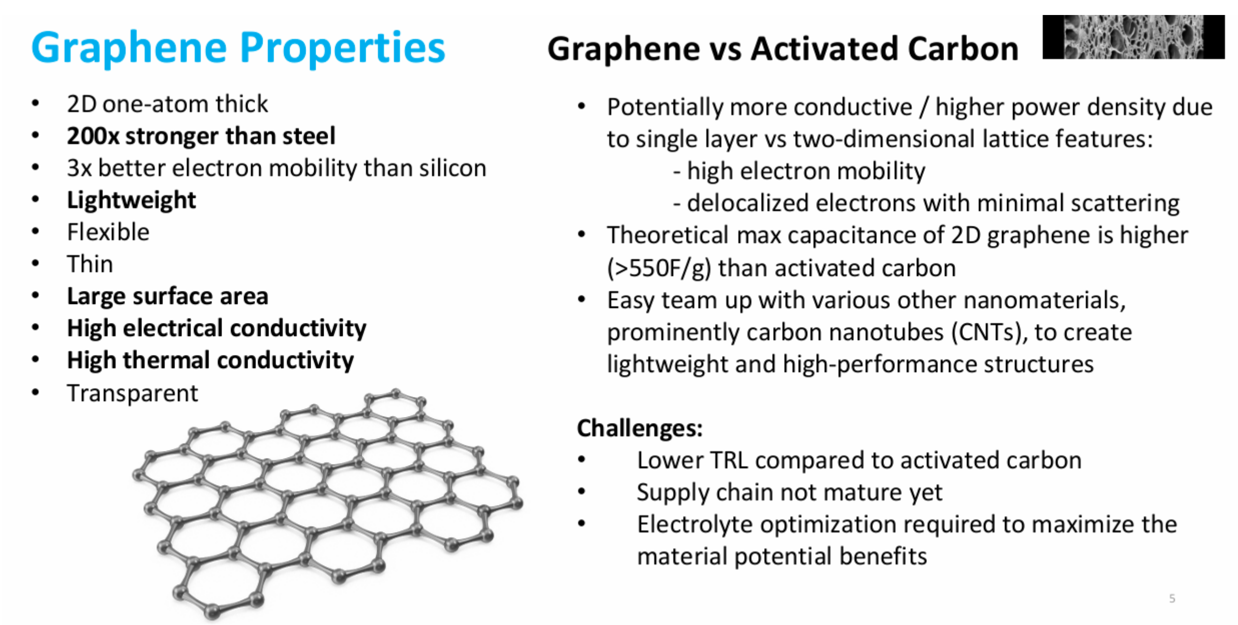

Fig. 14. Graphene's properties make it a potential performance booster as an electrode in supercapacitors.

With that as general background on graphene, Zednicek introduced a graphene material called SC-GN3 developed by the Czech Advanced Technology and Research Institute (CATRIN) and Palacky University in the Czech Repulblic. This material offers both high energy and high power density, giving it the potential to fill the performance gap between supercapacitors and batteries.

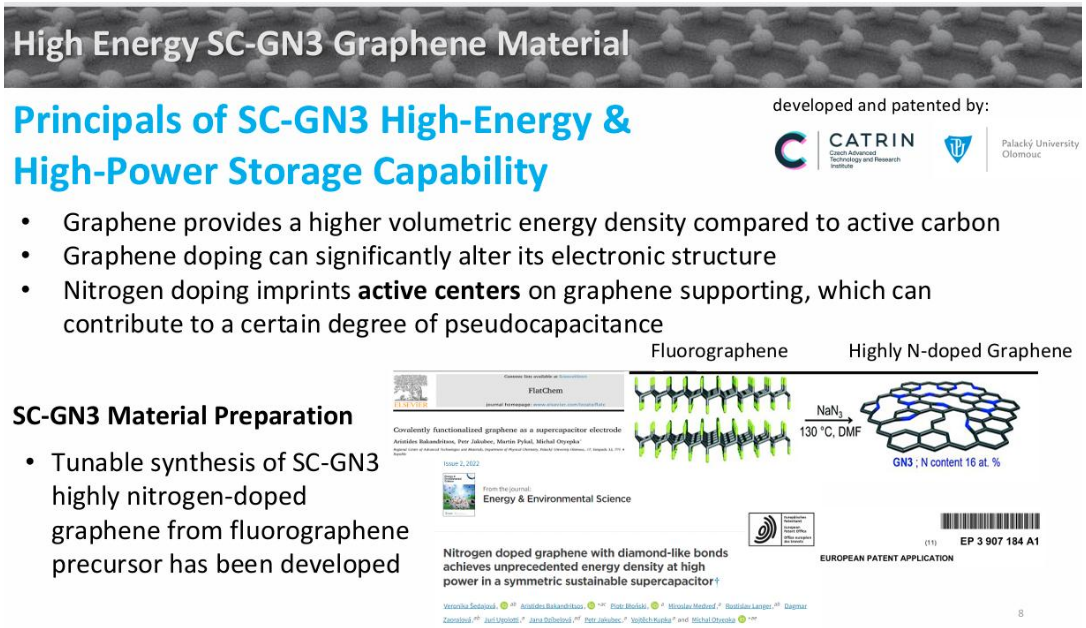

Fig. 15. In research funded by the EU, the Czech Advanced Technology and Research Institute (CATRIN) and Palacky University have developed a graphene material called GN3, which has enabled development of supercaps with high volumetric energy density.

While the active material itself has a potential energy density of 200 Wh/l, based on pouch cell prototypes developed by Bar Ilan University in 2023, it's projected that commercial supercapacitor cells will achieve a volumetric energy density of 50 Wh/l compared with 4 Wh/l for currently available supercaps in pouch cells and the 16 Wh/l now available for supercap cylindrical cells. In addition, supercaps based on SC-GN3 will achieve a gravimetric energy density of ~55 Wh/kg and a power density of 2 to 50 kW/kg. See Figs. 16 and 17.

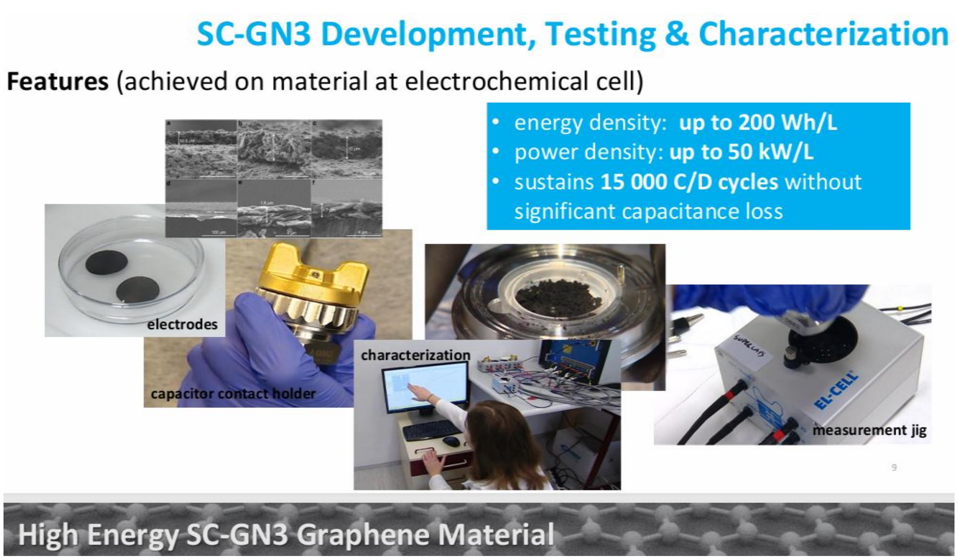

Fig. 16. SC-GN3 graphene has demonstrated high energy density and power density, while also maintaining reasonably long operating life—longer than batteries although not quite on par with conventional supercaps.

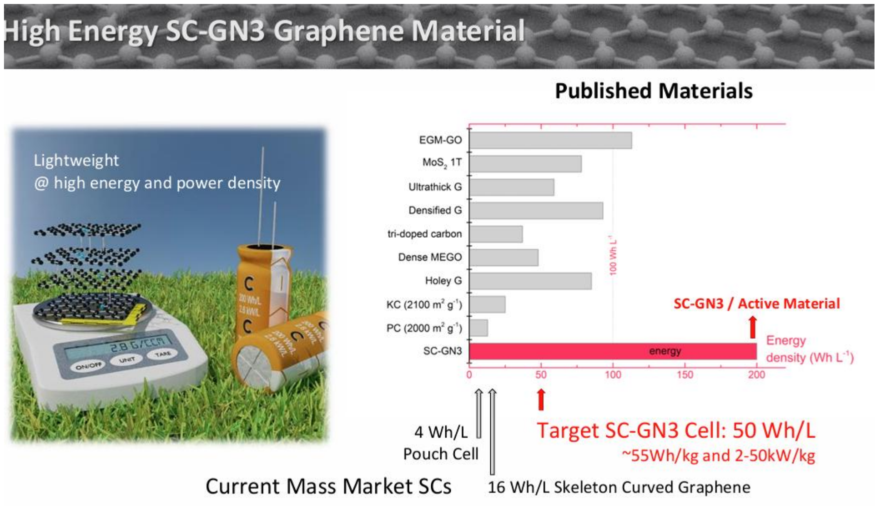

Fig. 17. Comparing energy density of GN3 versus other published materials. Performance goals for a commercial supercap cell based on this material are also shown and compared with mass market supercaps.

Another graphic given by Zednicek depicts how SC-GN3 capacitors will achieve battery-like energy density while maintaining power density comparable to or greater than existing supercaps (see Fig. 18).

Last year, the first wound-cell supercapacitor prototypes were developed by an Italian capacitor manufacturer, Itelcond, and a startup named Atomiver was spun out of Palacky University to create a commercial source for SC-GN3 graphene. Atomiver is responsible for developing and commercializing the SC-GN3 material supply chain, and has already begun scaling up production of the material and verifying the reproducibility of its processes, according to Zednicek.

Further work is to be done to ready this material for use in capacitor production. Zednicek noted in his remarks that Atomiver is currently evaluating multiple suppliers of fluorographene. However, the first prototype samples of foil pouch and wound cells are scheduled to be produced this year and evaluation of these cells is expected to be completed by Q3 (sometime this autumn). According to Zednicek, one of the biggest challenges in developing these prototypes will be selecting the right electrolyte.

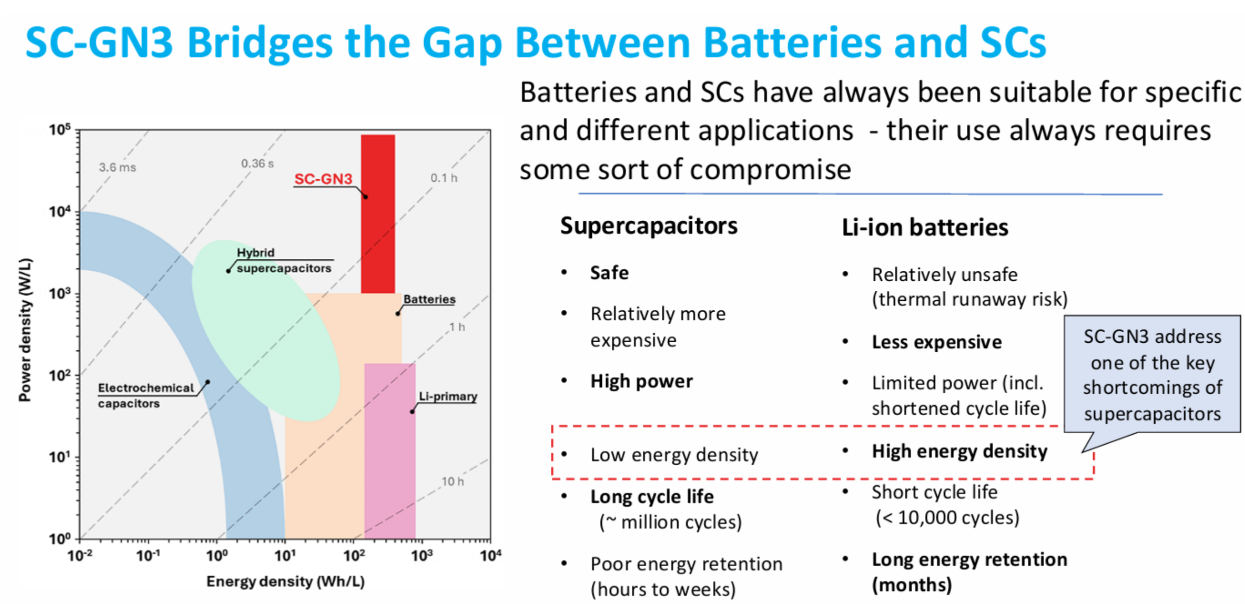

Fig. 18. Supecaps based on GN3 offer energy storage options that mitigate the tradeoffs usually made when choosing between supercaps and batteries.

More details are provided in Zednicek's presentation[9] on the timeline and industrial processes required for development and commercialization of the SC-GN3 material, and the steps required for assembling pouch and wound cells.

Atomiver will be collaborating with others to establish manufacturing capabilities for SC-GN3-based supercaps in Europe mainly for the benefit of aerospace, defense or medical industries. This work was enabled by the EIC Transition project entitled "Transition of 2D chemistry-based supercapacitor electrode material from proof of concept to applications" (TRANS2DCHEM) No.101057616 funded by the European Union. It also received funding through the NATO DIANA project (https://www.diana.nato.int/about-diana.html). For more information, contact Tomas Zednicek.

References

1. "Heterogeneous Integration in Complex Integrated Microelectronics Systems" by Richard Otte, Promex QP Technologies, presentation at CMSE 2024.

2. "What is Heterogeneous Integration (HI)?" on ASE website, accessed June 6, 2025.

3. "Integrated Power Electronics for Heterogenous Integration" by Hanh-Phuc Le, PowerSoC 2024.

4. "APEC 2025: Industry Crafts Vertical Power Delivery Solutions For AI Processors" by David Morrison, How2Power Today, April 2025. This article doesn't mention heterogenous integration specifically, but discusses the related concepts of vertical power delivery.

5. "Electronic Parts Standards: Past, Present and Future" by Lawrence Harzstark, CMSE 2025 plenary.

6. "Why Planar Magnetics are Ideal for Harsh Environments" by Jim Marinos, CMSE 2025.

7. "Benefits of a Hybrid Planar Transformer Package" by Jackson Sonterre, CMSE 2025.

8. "Advanced FastCap Capacitors for Military and Space Electronics And Embedded Solutions" by Christopher Deane, CMSE 2025.

9. "Commercialization of GN3 Graphene Material as the Active Electrode for High Energy Supercapacitors" by Tomas Zednicek, CMSE 2025.