WHITEPAPER

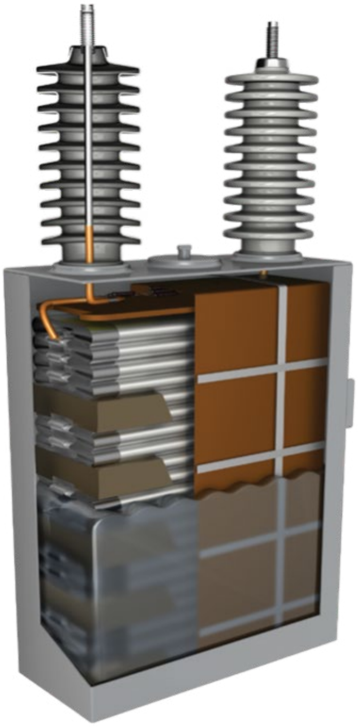
GETTING TO 1HZ SHOT RATE

From 2,160 to 352,800: The Capacitor Supply Chain That Commercial Pulsed Power Fusion Demands

CONTENTS

EXECUTIVE SUMMARY

The Impedance-Matched Marx Generator (IMG) represents the most significant advance in pulsed power engineering in a century. By eliminating all but one of the pulse compression stages found in legacy systems (which could have four or more stages), the IMG nearly doubles energy delivery efficiency from approximately 50% to 90%. This whitepaper traces the evolution of pulsed power technology from Erwin Marx's 1924 voltage multiplier circuit through the Z Pulsed Power Facility at Sandia National Laboratories to today's impedance matched architectures targeting 60+ MA for Magnetized Liner Inertial Fusion (MagLIF). It examines the private capital, hardware demonstrations, and scaling physics that have converged around IMG-based Z-pinch fusion as a commercially viable energy pathway and quantifies the capacitor supply chain that pathway demands.



One of the advantages for IMGs in MagLIF systems is that they replace very large and expensive custom-built capacitors with arrays of smaller production-manufactured ones. Similarly, the switches in an IMG are also more easily scalable than those in a standard Marx generator, or in legacy pulsed powered electronics. An IMG replaces multi-megavolt SF_6 gas switches utilized in standard Marx generators with arrays of 200 kV dry-air switches that eliminate environmental and safety hazards. For instance, the current Sandia Z machine (which utilizes standard Marx generators) has 2,160 large custom-built oil-filled capacitors, while Pacific Fusion's Demonstration System has approximately 50,000 small low-cost capacitors, with a similar scaling of the gas switches that are part of the IMGs.

In any MagLIF system, the problem of scaling up the shot count from hundreds or a few thousand a year in a laboratory prototype to tens of millions of shots per year in a production fusion system is severe. The dominant dielectric material, biaxially oriented polypropylene (BOPP), stores approximately 2.4 J/cc with a practical temperature ceiling of 85°C. The mean shot life of BOPP capacitors is roughly 17,000 shots (cycles) at 100 kV. At the Hz-rate operation that commercial fusion demands, those capacitor specifications are insufficient.

Peak Nano's NanoPlex™ platform addresses these capacitor performance gaps directly. NanoPlex HDC delivers up to 4x higher energy density than BOPP for inertial confinement pulsed power and is 100% U.S.-engineered and manufactured with allied-sourced materials, providing supply chain security for fusion programs subject to International Traffic in Arms Regulations (ITAR) and Export Administration Regulations (EAR) requirements.

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THE PULSED POWER BASELINE

The Impedance Matched Marx Generator did not emerge from a vacuum. It is the product of a century of pulsed power engineering, each generation exposing the limitations that the next generation solved. Understanding the baseline is essential for understanding why the IMG's architecture creates both an opportunity and a supply chain challenge for capacitor film.

A Century of Voltage Multiplication

Erwin Otto Marx published his voltage-multiplying circuit in 1924 in *Elektrotechnische Zeitschrift*, originally to simulate lightning strikes for testing high-voltage insulators. The process involves charging *N* capacitors in parallel at voltage *V* through resistors, then discharging them in series through spark-gap switches to produce a pulse of approximately *N*×*V*. A 20-stage Marx Generator charged at 100 kV produces a 2 MV pulse. The architecture scales by adding stages.

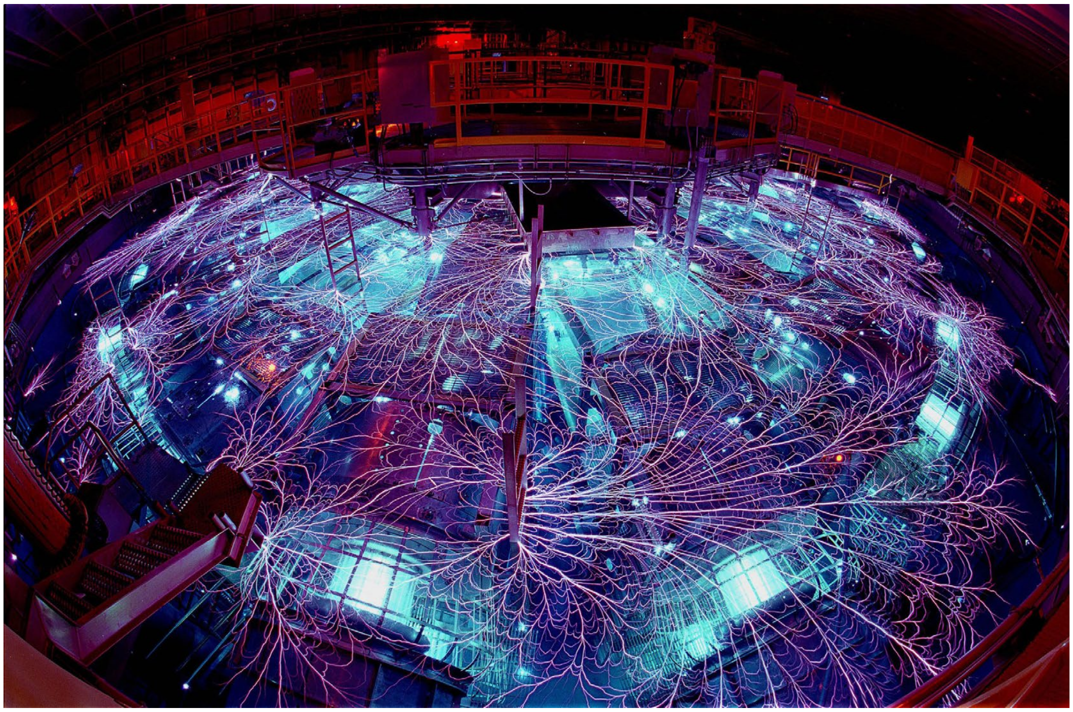
The technology reached Sandia National Laboratories through the work of J.C. "Charlie" Martin at the UK's Atomic Weapons Research Establishment and collaborators who brought pulsed power techniques to U.S. national laboratories during the Cold War. Sandia's 1969 Hermes II flash X-ray generator produced 10 MV, 100 kA, 50 ns pulses using Marx generator technology, establishing the pattern of using capacitor-stored energy to generate extreme electromagnetic conditions.

The most consequential application emerged in 1996, when Sandia converted PBFA-II from a particle-beam accelerator to a high-current Z-pinch driver and renamed it the Z Pulsed Power Facility. That conversion unlocked magnetic compression of cylindrical targets at multi-megaampere currents, producing X-ray powers exceeding 350 TW and temperatures above 2 billion degrees Kelvin. Z became the world's most powerful laboratory radiation source and the primary testbed for high-current Z-pinch fusion physics.

Inside the Z Machine

The Z Refurbishment Project (ZR), completed in October 2007 at approximately $90 million, replaced all pulsed power components while retaining the 36-module radial architecture. The upgrade doubled stored energy from approximately 11 MJ to over 22 MJ and increased peak current from 18 MA to 26-27 MA delivered to the central load in approximately 100 nanoseconds. Z remains the world's highest-current pulsed power facility.

Capacitor Demand Signal: Z's 2,160 expensive oil-filled capacitors each store approximately 13 kJ at 100 kV. In a prototype environment like the Z machine, these BOPP-dielectric capacitors operate at a modest 200 shots/year. Commercial fusion demands millions of shots per year from capacitors that must survive thermal cycling, voltage stress, and repetitive pulsing at rates the Z machine was never designed to approach.



Z's pulse compression chain reveals both the power and the limitations of the Marx architecture. Each of the 36 Marx generators contains 60 capacitors charged to ±85 kV, producing a 5.1 MV, approximately 1.3 μs pulse. But Z-pinch implosions require approximately 100 ns pulses. Bridging that 15x gap in pulse duration requires four sequential compression stages, each with its own set of switches, transmission lines, and energy losses:

First, Marx generators discharge into water-dielectric intermediate-store capacitors. Second, laser-triggered gas switches operating at up to 5.4 MV in SF_6 gas release energy into pulse-forming lines. Third, those lines compress the pulse to approximately 200 ns at 700 kA. Fourth, self-breaking water switches fire the final pulse into the magnetically insulated transmission lines (MITLs) that deliver current to the central load. Each stage dissipates energy. The cumulative result is approximately 50% wall-plug-to-load efficiency, meaning Z must store roughly 22 MJ to deliver approximately 11 MJ.

> **Z remains the world's highest-current pulsed power facility.**

MagLIF and the Case for 60 MA

The reason the fusion community cares about reaching 60 MA is Magnetized Liner Inertial Fusion (MagLIF), conceived by [at Sandia]() and first demonstrated experimentally in November 2013. **MagLIF merges three elements.**

An axial magnetic field of 10-20 T is pre-imposed on deuterium-tritium fuel inside a cylindrical beryllium or aluminum liner.

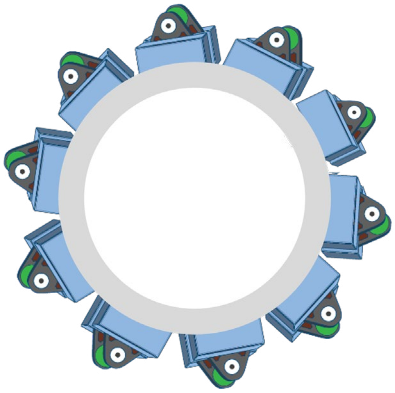
A laser pulse preheats the fuel to 200-400 eV.

A multi-mega-ampere current pulse, delivered in approximately 100 ns, implodes the liner at 70-100 km/s, compressing both the fuel and the trapped magnetic field.

The physics of a MagLIF system is significantly different from a laser-based inertial confinement fusion (ICF) machine. A typical laser ICF machine such as the National Ignition Facility (NIF) compresses a spherical capsule to extreme convergence ratios at velocities exceeding 350 km/s, relying on precise symmetry to create a central hot spot. On contrast, a MagLIF machine compresses a cylinder at much lower velocity, but the magnetic field, squeezed to thousands of tesla by the implosion, suppresses thermal conduction losses from the hot fuel. This magnetic insulation reduces the required implosion velocity, pressure, and symmetry, making the engineering requirements more tractable at scale.

MagLIF performance on Z has improved dramatically. At 20 MA, experiments have achieved 1.1 x 1013 deuterium-deuterium (D-D) neutrons with ion temperatures of 3.1 keV, a 30x improvement over five years. The scaling physics is favorable: neutron yield increases roughly as the eighth power of current, meaning a 3x increase from Z's 20 MA to 60 MA could increase fusion yield by roughly 6,500x. At 60 MA with optimized targets, simulations project yields sufficient for net energy gain with target gain factors of 100 or more.

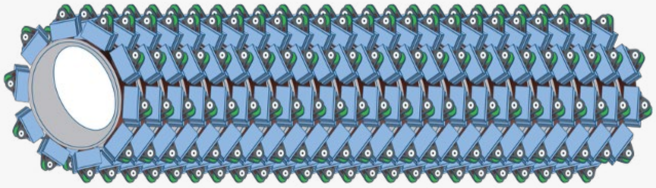
Better pulse shaping is critical to realizing this potential. MagLIF implosions are vulnerable to magneto-Rayleigh-Taylor (MRT) instabilities that deform the liner and mix cold metal into hot fuel. Tailored current profiles that ramp gradually before a sharp rise can suppress MRT growth; a challenge for the Z machine's four-stage compression chain, which offers limited pulse-shaping flexibility. By contrast, an IMG enables arbitrary waveform generation and pulse shaping capabilities through independent timing of individual bricks.



The power blocks are arranged around a chamber cylinder to form a power stage

THE IMPEDANCE MATCHED MARX GENERATOR

William A. Stygar, then at Sandia National Laboratories, introduced the IMG concept in a [2017 paper in Physical Review Accelerators and Beams.]() The building block is the "brick": two relatively small capacitors (typically 80-160 nF, 100 kV each) are connected in series through a single 200 kV field-distortion gas switch. The switch uses filtered, dried air rather than SF_6. A complete IMG module stacks hundreds of bricks along a transmission line whose impedance matches the generator's output impedance. Bricks fire sequentially at the electromagnetic transit time between stages, launching a coherent traveling wave that arrives at the load with approximately 90% of the stored energy, in a single compression step.



Up to 150 stages are combined to form an IMG power module

Architecture and Performance Gains

The following table summarizes the architectural differences between legacy Marx-based pulsed power (as implemented in the Z machine) and the IMG:

PARAMETER	LEGACY MARX + PFL	IMG
Energy delivery efficiency	~50%	~90%
Stored energy for equivalent output	Baseline (1x)	6x reduction
Switch voltage	Up to 6 MV (SF_6 gas)	200 kV (filtered dry air)
Pulse compression stages	4 stages	1 stage
Capacitor energy per unit	~13 kJ at lethal voltages	400-800 J (inherently safer)
Pulse shaping	Limited flexibility	Arbitrary waveform generation
Hazardous materials	SF_6, lead electrodes	None (dry air switches)

The IMG also outperforms Linear Transformer Drivers (LTDs), the other leading next-generation architecture. LTDs achieve similar efficiency but require expensive ferromagnetic cores that become prohibitively costly at scale. The IMG uses no magnetic cores, relying entirely on electromagnetic wave propagation along matched transmission lines. This eliminates a major cost and manufacturing bottleneck.

From Theory to 330 Gigawatts

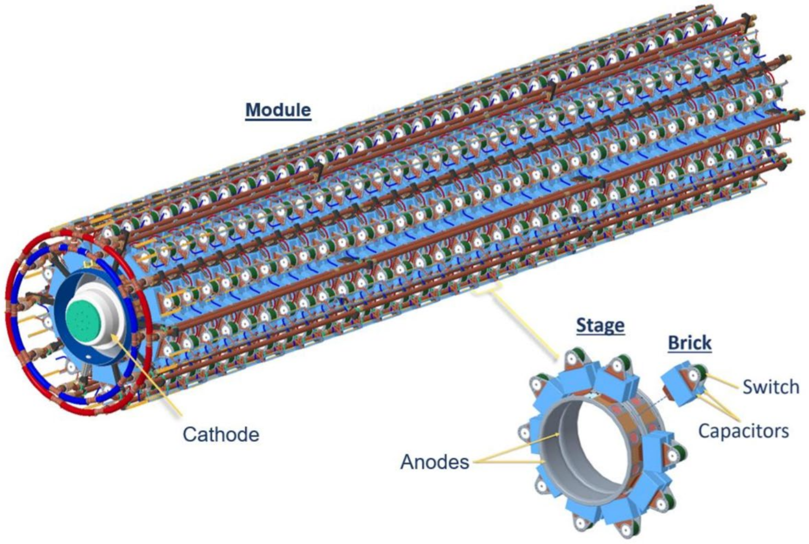
The transition from paper to hardware has been remarkably fast. At Lawrence Livermore National Laboratory (LLNL), the Sirius I prototype (4 stages, 8 bricks per stage) delivered 60 GW of power to an impedance-matched load in approximately 100 ns, matching theoretical predictions with striking precision and demonstrating 90% energy delivery efficiency. Sirius II, a 16-stage, 64-brick system designed to deliver 300 GW, is under construction at LLNL's Jupiter Laser Facility.

Independently, Fuse Energy Technologies built TITAN, a 14-stage IMG designed to deliver 1 TW to a 2-Ω load. The 6-stage testbed, containing 102 bricks and 102 gas switches, achieved 330 GW peak power in testing reported in Scientific Reports (Nature, 2024). Full 14-stage simulations predict 600 kA and nearly 1 TW into a matched load. TITAN validated IMG scaling at a power level relevant to fusion driver modules.

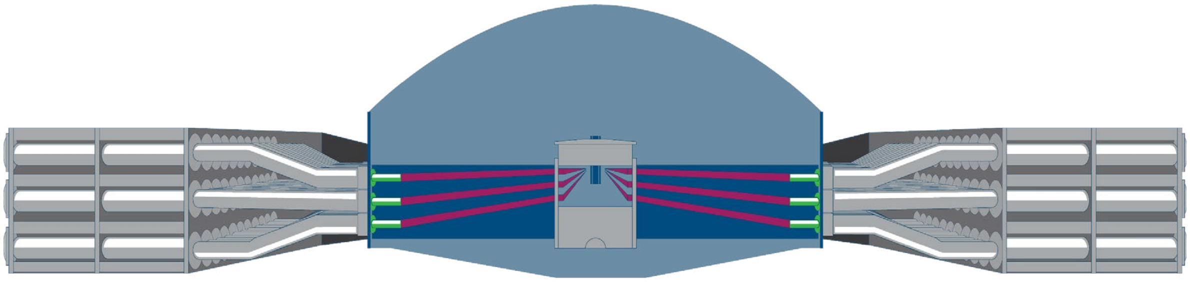
Fuse Energy plans Z-Star (approximately 2027): 16 TITAN modules delivering 15 TW and 12+ MA for MagLIF experiments at 1,000 shots per year. Their longer-term Apeiron-I concept envisions 90 modules producing 300-500 TW and approximately 50 MA.

Pacific Fusion's Demonstration System

Pacific Fusion, co-founded by IMG co-inventor Keith LeChien (former NNSA ICF director), has raised approximately $900 million and is building the largest IMG-based machine yet. Their Demonstration System (DS) comprises 156 identical pulser modules arranged in a spherical configuration around a meter-scale target chamber. Each module contains hundreds of bricks, with each brick consisting of two 160 nF capacitors storing 800 J at 100 kV and one 200 kV dry-air switch. The design builds directly on the AMPS architecture paper published in Physics of Plasmas.



The combined system stores approximately 80 MJ of electrical energy and targets delivery of more than 60 MA to a centimeter-scale MagLIF target in roughly 100 nanoseconds. The AMPS paper calculates that the demonstration system couples stored energy to fuel internal energy roughly 200x more efficiently than NIF's laser-driven approach, because electrical-to-kinetic conversion in a Z-pinch avoids the multi-stage energy conversion losses inherent in laser ICF (electrical-to-light-to-X-ray-to-kinetic).



In February 2026, Pacific Fusion and Sandia National Laboratories announced a significant simplification. In experiments at the Z Pulsed Power Facility, the team demonstrated MagLIF targets made of plastic and aluminum that generate their own internal magnetic field, eliminating the external magnetization coils and laser preheat window required by traditional MagLIF. This self-premagnetizing target concept removes two of the three subsystems that complicated Hz-rate MagLIF operation, leaving only the pulsed power driver and the target itself.

Capacitor Demand by System

SYSTEM	CAPACITORS	ENERGY/UNIT	STATUS
Z Machine (ZR)	2,160	~13 kJ	Operational
Pacific Fusion DS	~50,000	800 J	Phase 2
Fuse Z-Star	~1,600	~800 J	~2027
Sandia Neptune (concept)	~50,400	TBD	Conceptual
Sandia Jupiter (concept)	352,800	TBD	Conceptual

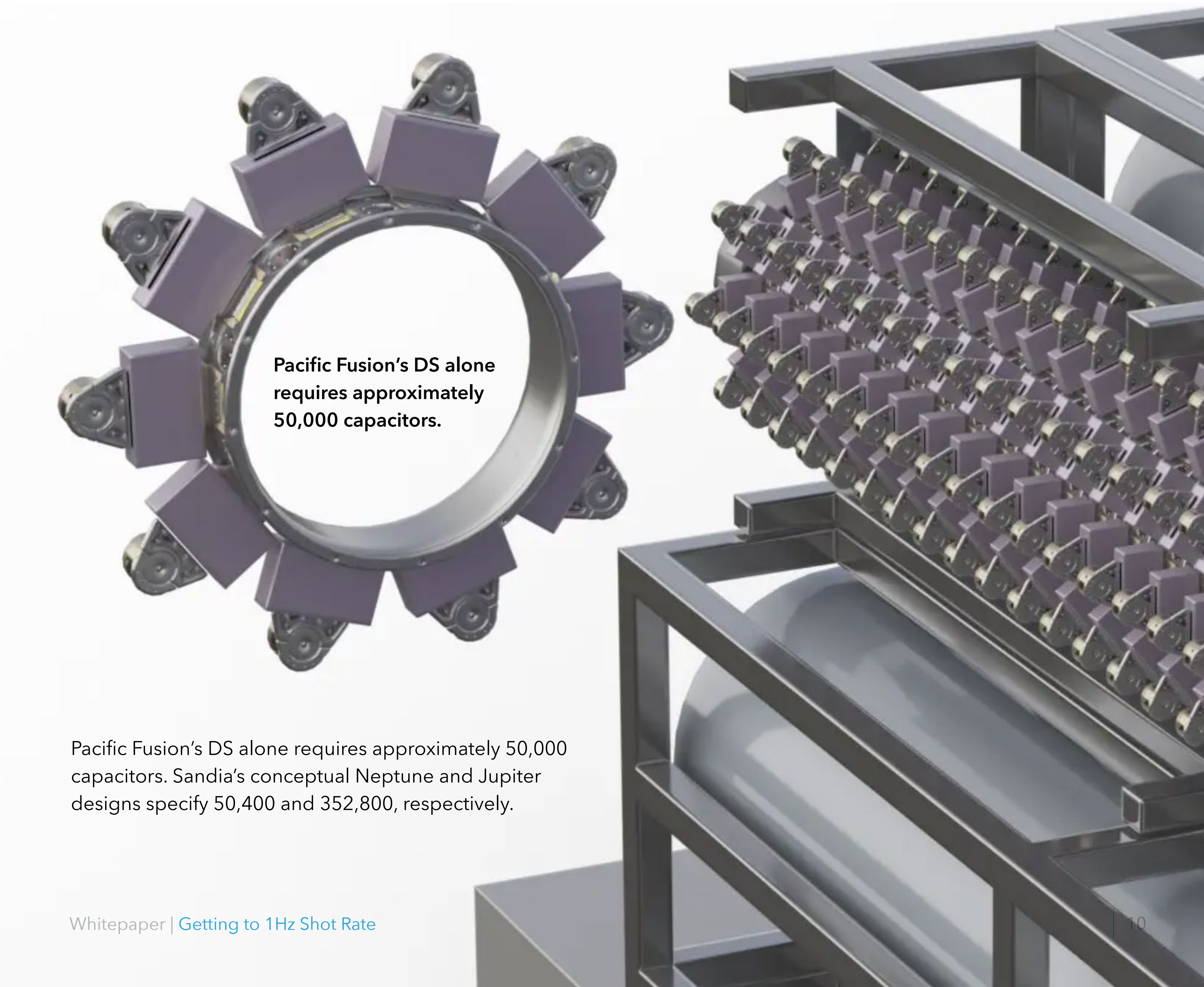
Scale Challenge:
The jump from thousands to tens of thousands of capacitors per facility, with commercial fleet scenarios pushing into millions annually, represents a manufacturing scale-up of two to three orders of magnitude. Every capacitor in these systems depends on the dielectric film at its core.

THE CAPACITOR PERFORMANCE CLIFF

Every production pulsed power fusion approach depends on a long life from its capacitors, and the supply chain is not prepared for either the performance or the scale that IMG systems demand. The qualified U.S. manufacturer base for extreme-duty pulsed power capacitors (100 kV, >10 kJ, high shot-life) is concentrated in a small number of firms. International sourcing is constrained by both technology readiness and regulatory restrictions.

High-performance capacitors for fusion and defense fall under ITAR controls (USML Category XI(c)(5)) and EAR dual-use restrictions (ECCN 3A001). This regulatory framework means that the dielectric film inside a pulsed power capacitor is a controlled material with national security implications.

IMG Systems: 50,000 to 352,800 Per Facility



Pacific Fusion's DS alone requires approximately 50,000 capacitors.

Pacific Fusion's DS alone requires approximately 50,000 capacitors. Sandia's conceptual Neptune and Jupiter designs specify 50,400 and 352,800, respectively.

A commercial fleet of ten fusion plants, each with a next-generation pulsed power system, could require millions of these high-performance, long-life capacitors annually when replacement cycles are factored in. Manufacturing equipment lead times for producing tens of millions of high-precision, 100 kV capacitors have not been established because no such demand signal has existed before.

Capacitors Beyond the Z-Pinch: Laser-Driven ICF

The capacitor demand from IMG-based Z-pinch systems represents only a fraction of the total fusion sector requirement. Laser-driven ICF systems also depend on Marx-generator-based pulsed power, not to drive Z-pinch loads directly, but to pump the laser amplifiers that produce fusion-relevant photons. Every laser-driven ICF approach requires stored electrical energy that is released in precisely timed pulses, and that energy is stored in capacitors.

Xcimer Energy (Denver, CO; $111M raised; DOE Milestone Program awardee) provides a concrete example. Xcimer's KrF excimer laser architecture uses Marx generators to produce high-current electron beams that pump the laser gas medium. According to Xcimer's commercialization whitepaper (Galloway, Valys, and Sutter, 2026), current capacitor costs are approximately $10/J of stored energy, with volume production at 3 MJ scale reducing costs to approximately $0.85/J and a target of $0.40/J at higher volumes. Xcimer has opened a proprietary capacitor manufacturing plant in Tucson, AZ to address this supply chain dependency.

Inertia Enterprises ($450M Series A, February 2026) is building a 10 MJ, 10 Hz diode-pumped laser system comprising approximately 1,000 modular laser units, each driven by capacitor-powered pump diodes. Focused Energy (over $175M raised) is developing compression and ignition lasers that similarly rely on capacitor-driven pulsed power for their pump systems.

The LLNL Roadmap Requirements

The LLNL pre-roadmapping report (Curry et al., 2025) identifies that energy storage costs must decrease 5-10x and component lifetimes must increase roughly 1,000x for commercial viability. Peak Nano Chief Scientist OfficerDr. Michael Ponting co-authored the report, contributing the nanolayered polymer perspective to a panel spanning national laboratories, academia, and industry. The report explicitly identifies advanced dielectric materials as a key enabling technology for meeting these targets. Current BOPP-based capacitors, designed for laboratory shot rates, do not meet the cost, lifetime, or energy density requirements that commercial fusion demands.

Challenges and Gaps in the Development of Pulsed Power for Fusion Applications: A Pre-Roadmapping Perspective from Industry, Academia, and National Laboratories Experts

August 14, 2025

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Lawrence Livermore National Laboratory

LLNL-JRNL-2001600

NNSA

WHY BOPP CANNOT KEEP UP

Biaxially oriented polypropylene has been the dominant capacitor film dielectric for decades, and for good reason. BOPP is well characterized, widely available, and performs reliably in the machines it was selected for. Nobody chose BOPP because it was the best possible dielectric. They chose it because it was the best available dielectric at the scale and cost the application required, and because the applications it served did not stress its limitations.

Research-Class vs. Commercial-Class Requirements

The transition from laboratory-scale to commercial-scale fusion changes every parameter that determines dielectric material selection. The following table quantifies the gap between BOPP's performance what commercial fusion requires:

PARAMETER	RESEARCH-CLASS	COMMERCIAL-CLASS
Shot rate	~200/year (Z); ~400/year (NIF)	0.25-1+ Hz (8M-31M shots/year)
Turnaround	Hours to days between shots	Seconds (continuous operation)
Capacitor thermal requirements	Climate-controlled; full cooling between shots	Cumulative heat from Hz-rate cycling
Required capacitor lifetime	~17,000 shots (decades at lab rate)	Billions of shots (LLNL: 1,000x increase needed)
Capacitor replacement model	Scheduled maintenance line item	Must be rare or eliminated
Cost driver	Scientific output per shot	Levelized cost of electricity (LCOE)
Capacitor count sensitivity	Low (one facility, 2,160 caps)	High (50,000-352,800 per facility; fleets of 10+)
Supply chain model	Single-source OK for one facility	Domestic, diversified, scalable required

Research-Class Machines

The Z machine fires approximately 200 shots per year, while NIF fires roughly once per day. Between shots, these facilities have hours to days of turnaround for diagnostics, target replacement, and maintenance. Capacitors operate in climate-controlled environments with dedicated engineering teams monitoring performance. At 200 shots per year, a capacitor with a 17,000-shot lifetime lasts 85 years. The dielectric is never the limiting factor.

Commercial-Class Machines

A commercial fusion power plant must fire at 0.25 to 1+ Hz continuously, around the clock, for decades. Capacitor replacement cannot be a primary maintenance activity because the economics of competitive electricity generation do not support it. Internal capacitor temperatures accumulate through repetitive charge-discharge cycling, and the cooling intervals that research-class machines take for granted do not exist.

At 1 Hz, BOPP's 17,000-shot mean lifetime is exhausted in under five hours. Its 85°C ceiling becomes a constraint because cumulative thermal loading from Hz-rate cycling pushes internal temperatures well above ambient even with active cooling. Its 2.4 J/cc energy density becomes a cost and footprint problem when the system requires 50,000 to 352,800 capacitors.

The material did not fail; the mission changed. BOPP remains a reasonable dielectric for the research-class machines it was selected for. The transition from research to commercial operation changes every parameter that drives material selection: shot rate, thermal environment, cycle life, cost sensitivity, and supply chain scale.

Where the Gaps Open

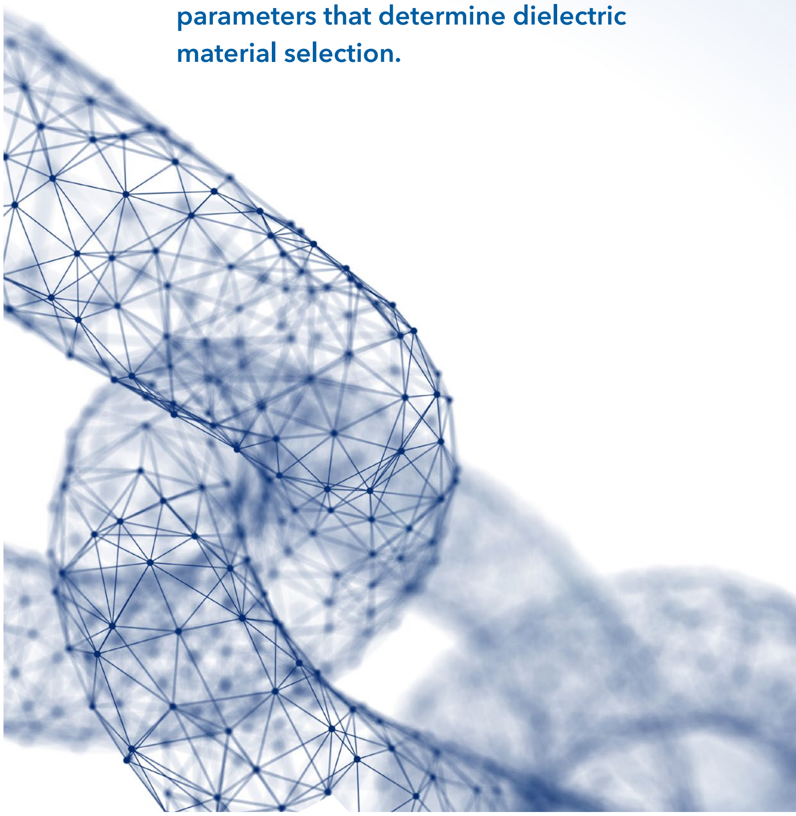
Every row in the table on the previous page shifts the material selection calculus. Energy density determines capacitor count and system footprint. Thermal endurance determines whether the dielectric survives cumulative Hz-rate cycling or requires active cooling that adds cost and complexity. Cycle life determines whether capacitor replacement is a minor maintenance item or a dominant operational cost. Supply chain scale determines whether a single-source procurement model is viable or whether domestic, diversified manufacturing is required.

Supply Chain Concentration

An estimated 70-80% of global capacitor-grade BOPP film production is concentrated in China. For fusion programs and defense applications subject to ITAR and EAR, this supply chain geography creates a dependency risk that intensifies as capacitor demand scales from thousands to hundreds of thousands per facility. A single Pacific Fusion DS requires approximately 50,000 capacitors. A fleet of ten commercial plants, factoring in replacement cycles, could require millions annually.

Manufacturing equipment lead times for producing tens of millions of high-precision, 100 kV capacitors have not been established because no such demand signal has existed before. The supply chain must scale by two to three orders of magnitude, and the dielectric film at the center of every capacitor must be sourced from production that satisfies U.S. regulatory requirements.

The transition from laboratory-scale to commercial-scale fusion changes the parameters that determine dielectric material selection.



THE NANOPLEX METAMATERIALS OPTION

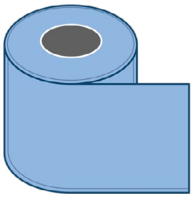
Peak Nano's NanoPlex nanolayered metamaterial films are engineered to close the performance and supply chain gaps that separate laboratory-scale pulsed power from commercial fusion operation.

NanoPlex HDC: Energy Density for Pulsed Power

NanoPlex HDC (High Dielectric Constant) is a nanolayered metamaterial film engineered for high-energy-density applications including inertial confinement fusion pulsed power, directed energy systems, and HVDC power conversion. HDC's nanolayer architecture, comprising up to 4,096 individual layers in films as thin as 8 μm, achieves dielectric constants of 3.8 to 4.9 (ASTM D150), compared to approximately 2.2 for BOPP, while maintaining breakdown strengths of 760-840 kV/mm (ASTM D149).

For ICF pulsed power applications, this translates to up to 4x higher energy storage per unit volume. In a system like Pacific Fusion's DS, where each brick stores 800 J across two 160 nF capacitors, higher energy density film enables either smaller capacitors at equivalent energy or higher energy storage at equivalent size. At the system level, HDC enables capacitor banks that are up to 50% smaller and 30% lighter, with corresponding reductions in facility footprint, transmission line length, and bill-of-materials cost.

NANOPLEX™
HDC



NanoPlex HDC provides 4x more energy storage

NanoPlex HDC Specifications

PROPERTY	METHOD	UNITS	HDC 4125	HDC 3125
Dielectric Constant	ASTM D150	1 kHz, 25°C	4.9	3.8
Dissipation Factor	ASTM D150	% at 1 kHz, 25°C	1.0	0.4
Breakdown Strength	ASTM D149	kV/mm	760	840
Shrinkage MD/TD @ 130°C	JIS K7133	%	<0.1 / <0.1	<0.1 / <0.1
Tensile Strength MD/TD	ASTM D638	MPa	63 / 57	57 / 55
Density	ASTM D792	g/cc	1.5	1.36
Max Operating Temp	-	°C	105	105
Thickness	-	Micron	8, 12	8, 12

NanoPlex HDC has demonstrated improved shot life over BOPP in a surrogate pulse power testbed system. For inertial confinement fusion applications where each shot delivers extreme voltage stress in nanosecond timeframes, NanoPlex HDC's combination of high dielectric constant, high breakdown strength, and improved shot life addresses the three material properties that most directly constrain IMG system design.

NanoPlex vs. BOPP: Performance Comparison

The following table summarizes how NanoPlex HDC addresses the specific performance gaps identified in current BOPP-based pulsed power capacitors for fusion energy applications. NanoPlex HDC targets inertial confinement pulsed power applications where energy density per shot is the primary driver.

REQUIREMENT	BOPP (CURRENT)	NANOPLEX HDC
Energy Density	~2.4 J/cc; Dk ~2.2	Up to 4x higher; Dk 3.8-4.9
Operating Temp	~85°C ceiling	Up to 105°C
Cycle Life	~17,000 shots at 100 kV	Improved shot life vs. BOPP
Dissipation Factor	~0.02%	0.4-1.0%
Breakdown Strength	~600-650 V/µm	760-840 kV/mm
Footprint Reduction	Baseline	Up to 50% smaller banks
Supply Chain	70-80% China origin	100% U.S. manufactured
Best Fusion Fit	Lab-rate (200 shots/yr)	ICF, directed energy, HVDC

HDC for energy density. NanoPlex HDC is optimized for pulsed power energy density. HDC addresses the energy density challenge, storing more energy per unit volume to reduce capacitor counts and system footprint.

Fully U.S.-Engineered, Allied-Nation Supply Chain

Peak Nano's NanoPlex platform is 100% U.S.-engineered and manufactured with allied-nation supply chains. This provides fusion program managers, defense procurement officials, and commercial energy developers with a domestic source of advanced dielectric film that satisfies ITAR and EAR compliance requirements without dependency on Chinese film imports.

NanoPlex is protected by over 20 global patents covering the core nanolayer technology, manufacturing processes, and product implementations. Peak Nano's Films as a Service (FaaS) platform enables rapid design, prototyping, validation, and scaling of custom nanolayered polymer films, with prototypes delivered in as little as three weeks for application-specific evaluation.

NanoPlex films are drop-in compatible with existing BOPP metallizing and winding equipment, enabling capacitor manufacturers to upgrade dielectric performance without retooling production lines. This compatibility accelerates adoption and reduces the capital barrier for capacitor OEMs evaluating advanced dielectric alternatives.

THE PATH FORWARD

The pulsed power approach to fusion energy operated for decades on roughly 1% of the total funding dedicated to laser ICF and magnetic confinement, according to the 2018 JASON report on Prospects for Low Cost Fusion Development. Despite that funding disparity, MagLIF on Z has achieved the second-highest Lawson parameter of any ICF experiment, and the IMG architecture has eliminated the engineering barriers that prevented Z-pinch systems from competing with laser facilities for scientific output. The capital markets have responded: Pacific Fusion, Fuse Energy, and a growing ecosystem of pulsed power component suppliers are building the hardware.

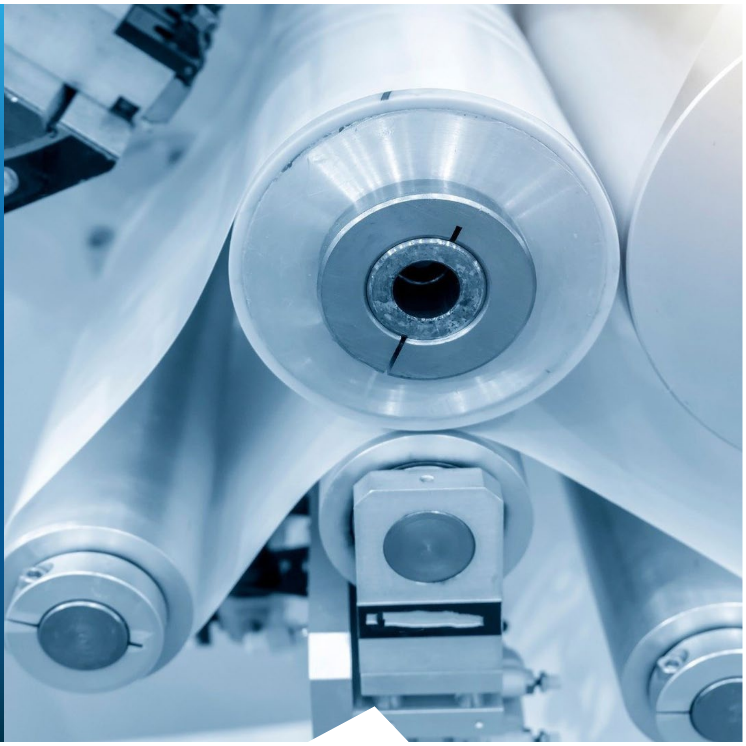
The timeline is shrinking as these technologies race towards commercialization. Pacific Fusion targets net facility gain by 2030. Fuse Energy plans Z-Star operations around 2027. Component orders for these machines will be placed within the next two to three years. For the fusion community, the IMG represents the moment when pulsed power ICF transitioned from a physics experiment to an engineering program with procurement timelines.

Whether the first commercial fusion power plant uses Z-pinch compression or an approach not yet developed at scale, the capacitor banks at its foundation will fire billions of times over a multi-decade operational life. The dielectric film inside those capacitors will determine their energy density, thermal endurance, shot life, the levelized cost of the electricity they help produce, and ultimately the viability of the approach itself.

Evaluating advanced dielectric films for pulsed power capacitors?

NanoPlex HDC films are qualified for the energy density and shot life that next-generation fusion and directed energy systems require.

Explore NanoPlex for Fusion Energy or contact sales@peaknano.com to request a sample kit.



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