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China's Hidden Quest to Win in Pulsed Power Fusion

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Summary

China's Launch into Fusion

The Chinese government views mastering fusion energy as a strategic national imperative with implications for energy independence, scientific discovery, and, in specific contexts, advanced strategic weapons systems. Heeding President Xi Jinping's call to increase China's technological self-reliance in strategic emerging technologies, China's leading military and civilian research institutions are systematically advancing and scaling innovative fusion energy technologies. They have invested around $10 billion across a large number of new projects, from new research labs to full-scale demonstration facilities.

China already dominates other advanced energy technologies and materials and is well on its way to leading in nuclear power. One expert referred to[1] the country as already "the de facto world leader in nuclear [fission] technology." So it is no surprise fusion is next on China's radar.

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IGCC

IGCC Policy Brief
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China's Ace Up its Sleeve: Inertial Fusion

China's fusion progress is typically described by its development of tokamaks[2]—donut-shaped machines that create a magnetic field capable of stabilizing plasma and enabling fusion reactions. Tokamaks and the powerful magnets that drive them play a large role in the recent influx of an estimated $6.5 billion into building advanced fusion projects.

However, less attention is paid to China's rapidly expanding lead in *inertial confinement fusion (ICF)* technologies. Long used in national security applications, China, like the United States, is increasingly developing civilian energy applications for ICF as well.

The China Academy of Engineering Physics (CAEP; 中国工程物理研究院), a PLA-led nuclear weapons development institution located in Mianyang, Sichuan province, is ramping up large-scale ICF infrastructure projects as China's top leadership seeks to increase the reliability and potency of its nuclear deterrent.

CAEP is simultaneously leading the charge to leverage this infrastructure to overtake the United States in the race to develop commercially viable fusion technology.

With three new ICF fusion systems actively under construction and two in late-stage planning, compared to zero in the United States (see Figure 1), CAEP is set to give China an edge in advanced ICF technology. In January 2025, in particular, news broke that CAEP is currently constructing[3] a laser-driven ICF facility, which experts believe will be called the Shenguang-IV, that is estimated to be at least 50 percent larger than the United States' National Ignition Facility (NIF). CAEP, much like the rest of China's nuclear weapons[4] industrial complex, is undergoing rapid expansion of its scientific facilities (see satellite image Figure 2).

FIGURE 1.
Planned ICF Facilities in China and the United States

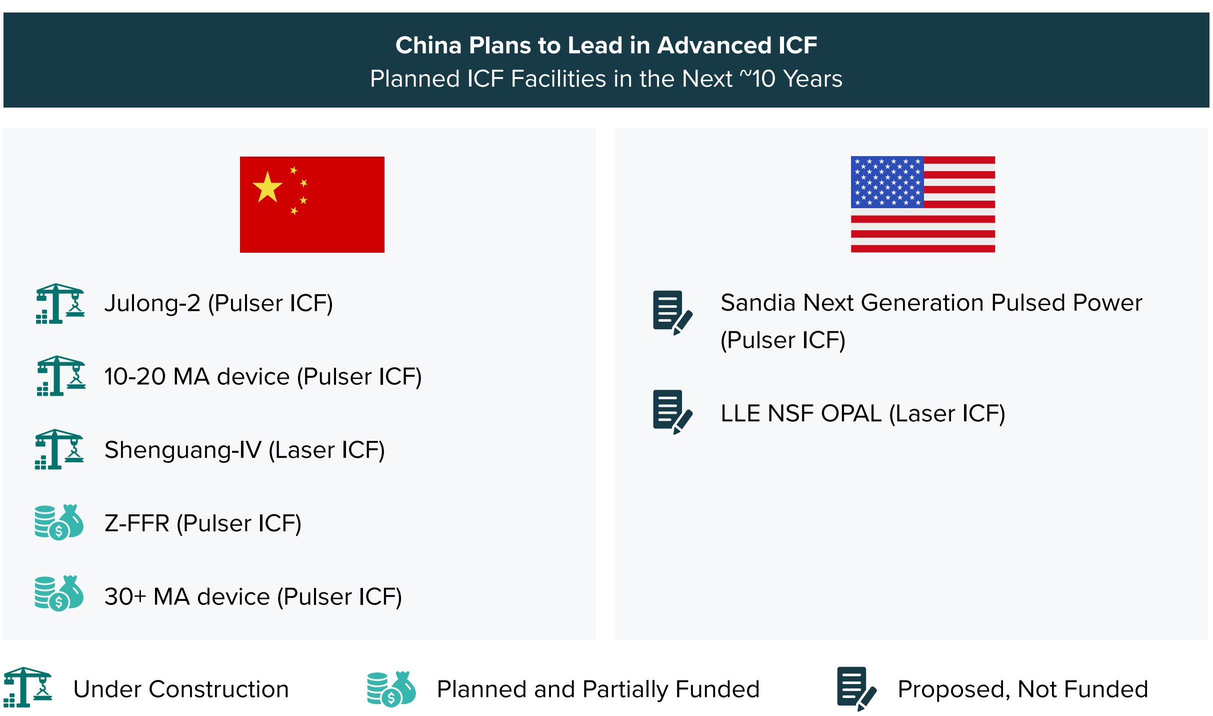


FIGURE 2.
CAEP Construction December 6, 2025 (Airbus)

FIGURE 3.
Ongoing Construction of a Better-Than-NIF Laser ICF Facility at the CAEP Campus in Mianyang, Sichuan, November 24, 2025 (Airbus)

China's ability and willingness to rapidly construct such large-scale infrastructure underscores[5] the country's determination to win the fusion race and advance nuclear weapons capabilities. For example, China's CAEP is recruiting[6] 2,000 scientists, engineers, and other experts into its inertial fusion programs, with thousands more anticipated. This is nothing short of a "whole-of-nation" effort, as described by Beijing.

Aside from powerful lasers, China could also soon take the lead in another very important approach to ICF—*pulsed power fusion*. Pulsed power stores energy in large capacitors and releases it in a sudden burst, producing extremely high power for a brief moment, like a controlled lightning bolt. Historically, the world's nuclear weapons states have leveraged pulsed power for weapons effects testing. But pulsed power systems have also opened up a promising commercial pathway because they are much more efficient than other fusion approaches in using the input electricity to create fusion conditions. Pulsed power's efficiency advantage makes it easier and more economical to make net power.

On the defense side, China's rapid buildout of these diversified fusion capabilities could enable development of lighter, higher-yield warheads with improved accuracy and enhanced hardening against nuclear effects—results the United States simply could not achieve with today's facilities, even, in some cases, accounting for underground nuclear testing.

On the commercial side, China is racing to build civilian-oriented pulsed power facilities to lay the foundation for fusion energy systems that could eventually power the world. As one example, China officially included building a next-generation pulsed power machine into its 14th Five-Year Plan, and to this end is already building a hybrid fusion-fission system called[7] Z-pinch driven fusion-fission reactor (Z-FFR), with plans to operate it by 2031.

That machine will, if built, surpass the current operational capabilities of the United States. Z-FFRs—pulsed power-driven hybrid fission-fusion reactors that "pinch" plasma to trigger fusion reactions—were first proposed[8] by the United States in the early 2000s by researchers at Sandia National Laboratories. However, that program was severely limited by a lack of funding—an issue stifling the United States' publicly financed fusion pathways today. In China, funding issues do not stand in the way of advancing pulsed power fusion.

China's Z-FFR plans start with the interim step of building a demonstration facility called Julong-2—a planned massive 50 MA (millions of Amperes) pulsed power project based in Sichuan province that would already be superior to Sandia's Z machine, currently the world's most powerful pulsed power facility. The Julong-2 and another Z-pinch plan currently undergoing testing have a combined projected investment of approximately $2.3 billion.

China's planned pulsed power buildout is set to give the country strategic deterrent simulation capabilities on par with or surpassing that of the United States—and a decisive advantage in the global race for fusion energy leadership.

In addition to constructing large-scale scientific infrastructure such as the new laser and pulsed power facilities, Chinese military and civilian institutions are working rapidly to build a more powerful pulsed power ecosystem, talent base, supply chain, and devices they believe are required to realize the country's Z-FFR ambitions.

The Chinese state's need to modernize its nuclear weapons deterrent and seek energy self-sufficiency is the driving force behind China's fusion endeavors, including those in pulsed power. Plus, China's push to develop fusion aligns with Xi's goals for technological self-reliance, which he has called "the foundation of national strength and the key to security."

Photo: Randy Montoy, CC BY-NC-ND 2.0

America's Advantage: Public-Private Partnerships

China's fusion effort draws on the strengths of its central planning and state-supported commercial approach. The country has already amassed a surmisable lead in ICF approaches that is set to grow by 2030 as next-generation facilities begin to come online. In terms of ecosystem—workforce, facilities, financial support, talent, and supply chain strength—China's only peer countries in pulsed power are the United States and Russia. China's pulsed power research, development, and commercialization ecosystem has demonstrably surpassed Russia and now equals and potentially surpasses the equivalent ecosystem in the United States.

This paper focuses on identifying the challenge posed by China's fusion ICF program, but it's worth noting a potential solution exists in the burgeoning private fusion sector in the United States. There are already inertial fusion energy companies, including those that leverage pulsed power approaches, actively building demonstration systems that are on the scale of the facilities China is constructing. If it starts now, the U.S. government can leverage the work being done by the private sector through public-private partnerships to catch up and maintain dominance both in national security and energy applications of fusion.

Introduction: China's Inertial Fusion Ecosystem

China and Pulsed Power

Beijing is attempting to increase the reliability and potency of its nuclear deterrent. At the same time, CAEP, China's ICF leader, is advancing China's efforts to overtake the United States in the race to develop advanced ICF technology.

The country has three new ICF fusion systems actively under construction and two in late-stage planning. The United States has zero. CAEP is currently constructing a laser-driven ICF facility, which experts believe will be called the Shenguang-IV, that is estimated to be at least 50 percent larger than the United States' NIF. CAEP, much like the rest of China's nuclear weapons industrial complex, is undergoing rapid expansion of its scientific facilities.

Like America's, China's drive to advance pulsed power fusion is fueled[9] by both civilian and military ambitions. Pulsed power systems are common civilian technologies that have a variety of applications, such as in particle accelerators and industrial systems.

At the same time, when used in a very specialized manner and with specific target designs, pulsed power has been an essential technology used by nuclear weapons states[10] to model nuclear weapons and develop new military technologies. In these cases pulsed power can help high-energy density physicists to create conditions similar to powerful explosions, akin to those of a nuclear bomb or a star forming within nanoseconds, in a contained and controlled environment, in hundreds of *nanoseconds*.

Accordingly, like the United States, China's premier pulsed power projects are housed within institutions leading the nation's nuclear weapons research. Pulsed power systems are primarily developed for nuclear weapons effects testing but are also being oriented towards civilian fusion energy development.

FIGURE 4.
Z Machine, Sandia National Laboratories. Electrical discharges illuminate the surface of the Z Machine operated by Sandia National Laboratories in Albuquerque, New Mexico, during testing.

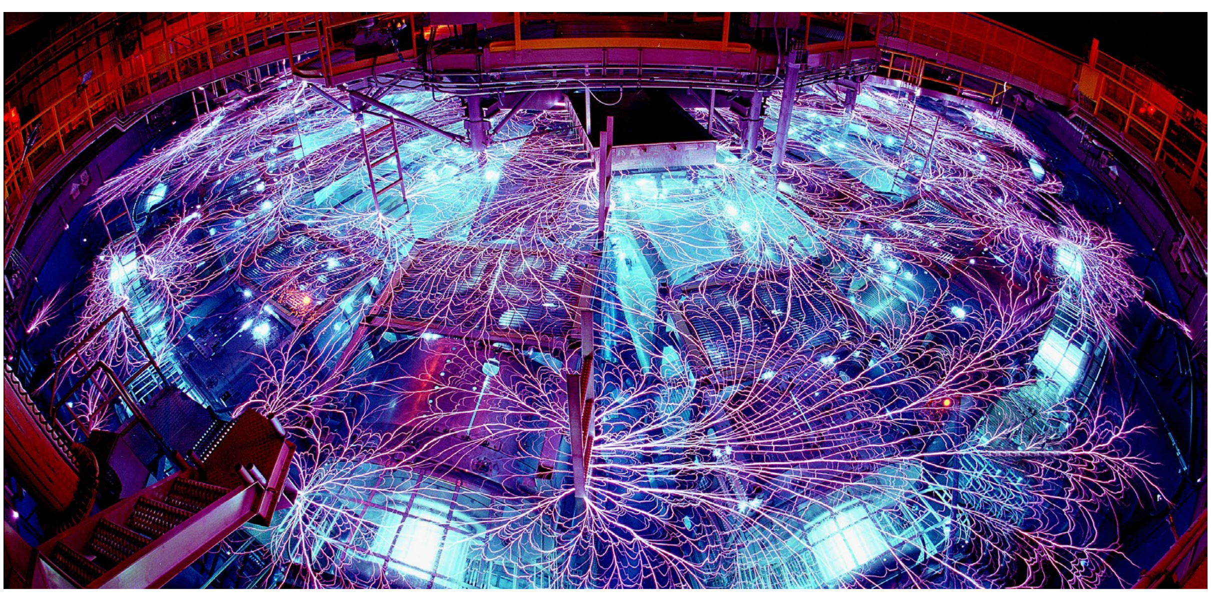


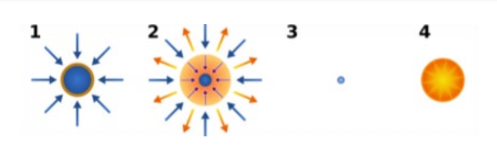
Photo: Randy Montoya, CC BY-NC-ND 2.0

FIGURE 5.
Simplified Comparison of Laser- and Pulsed Power-Driven ICF

Intertial Confinement Fusion (ICF)
A method for achieving nuclear fusion by rapidly heating and compressing a small pellet of fusion fuel (usually deuterium and tritium) using powerful lasers or other drivers.

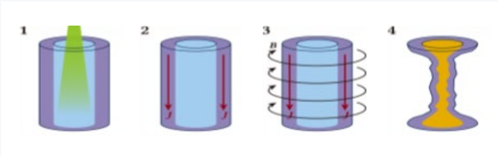
Laser-Driven ICF

- Powerful lasers head the outside of a tiny fuel pellet.
- The surface blows off, forcing the inner fuel to implode.
- The core reaches extreme density and temperatures (like the sun's core).
- Fusion burns spreads through the pellet, releasing more energy than the input.



Pulsed Power ICF (Z-Pince/MagLIF)

- A small laser first preheats the fusion fuel.
- A huge electrical pulse sends current through a metal cylinder (liner).
- The current creates magnetic fields that crush the liner inward.
- The implosion squeezes and heads the fuel, driving fusion reactions.



China's top military research institutes, especially the CAEP, are leading[11] the push to unlock ICF energy. They are pursuing two main approaches: one that uses powerful lasers to compress fuel and another that relies on giant bursts of electricity known as pulsed power.

China's existing ICF and broader pulsed power-related projects include the Qiangguang machines (which deliver enormous electrical pulses), the Shenguang laser series, and the Julong devices that use a "Z-pinch" effect to squeeze plasma with magnetic fields. See a full list of China's operational and planned pulsed power facilities in Figure 7.

However, China is also building fast. There are at least three new large facilities under construction, each more powerful than the analogous system that currently exists in the United States. In particular, CAEP is constructing a new laser fusion facility called Shenguang-IV, modeled on the United States' NIF. Satellite images suggest it will likely eventually surpass NIF in the energy it can generate. This facility would mark a symbolic and strategic milestone for China, signaling scientific progress in the global race for fusion energy as well as technological leadership in a field with major implications for clean power and national defense.

Much like the United States, Chinese scientists at CAEP and other institutions have for decades openly discussed[12] the strategic importance of high-energy-density physics (HEDP) for China's nuclear weapons modernization. CAEP scientists have also said[13] that all HEDP research in the near- and medium-term will be "focused on serving strategic defense applications" as well as civilian nuclear fusion energy research.

FIGURE 6.
Types of Pulsed Power Machines

Types of Pulsed Power Machines
Pulsed power devices store electrical energy, compress it in time and space, and deliver it to a target as strong, short, fast-rising pulses of power and can be categorized by the conditions created when the pulse hits the target.

Implosion Drivers (Z-pinch)

Quickly crush targets with magnetic fields to create x-rays and star-like plasmas.

- Fusion Research
- Weapons Effects Testing

China: Julong-1
US: Sandia Z Machine

Instant X-Ray Cameras (Flash Radiography)

Produce a bright, nanosecond x-ray burst to "photograph" fast, dense events.

- Weapons Testing
- Dynamic Imaging

China: Dragon-2
US: DARHT-II

Tabletop Plasma Labs

Create small, controlled plasmas for precise study and instrument testing.

- Basic Research
- Diagnostic Calibration

China: Qin-1
US: XP (Cornell)

What is pulsed power?

Pulsed power machines store electrical energy and drive large electrical current pulses through a small target within a fraction of a second to drive fusion reactions. They have a wide range of applications in high-energy-density physics (HEDP), the study of matter under extreme temperature and pressure. Specific configurations of pulsed power facilities are vital for driving fusion energy breakthroughs and improving understanding of nuclear weapons' effects and reliability, and they have enabled U.S. stockpile maintenance without underground testing.

The United States has historically led the development of pulsed power, and currently operates the world's most powerful system, known as the "Z-Machine" at Sandia National Labs.

But, driven by state support, China is catching up. China now has four major pulsed power facilities, embedded within the (1) China Academy of Engineering Physics, (2) Northwest Institute of Nuclear Technology, (3) Xi'an Jiaotong University, and (4) Tsinghua University.

Pulsed Power and National Security

Aside from enabling China to leapfrog the United States in the race for commercial fusion, China's systematic development of advanced laser- and pulsed power-driven ICF technologies will also yield significant military advancements that may considerably strengthen Beijing's overall strategic nuclear deterrent, giving China stronger cards to play in the event of possible future crises[14] over Taiwan, the South China Sea, or a broader conflict. For example, the Shenguang-IV, Julong 2, and Qiangguang-2 devices described in this paper could, when fully built, allow China to simulate, design, and test nuclear weapons on par with or surpassing current U.S. nuclear weapons science capabilities. Coupled with high-performance computing, this could aid China in developing higher-yield, lighter nuclear warheads, enabling faster, more accurate missile trajectories, as well as enhanced hardening of warheads, missiles, satellites, communications, and electronics against nuclear effects.

Given China is diversifying its nuclear warhead type and delivery mechanisms to include air, ground, and submarine-launched nuclear warheads, these facilities will be essential to help Beijing not only validate, but also enhance their potency and effectiveness. For example, China could develop new ways to shield its warheads[15] from any defense mechanism funded under the new U.S. "Golden Dome" initiative. China could also use these facilities to advance the science needed for exotic weapons capabilities like nuclear-pumped lasers in space[16], or new advanced triggers. Pulsed power technology is also fundamental[17] to developing High Power Microwave (HPM) weapons systems capable of delivering intense and disabling[18] electromagnetic pulses to critical infrastructure. These capabilities may bring new strategic deterrent capabilities to the People's Republic of China (PRC) that could match or exceed those of the United States.

It is no surprise, then, that Chinese researchers have described[19] their field as critical for national security as well as energy security. According to one scientist, "research on Z-pinch-driven fusion and high energy density physics is in the ascendant, and has important applications in national defense." Another noted that large-scale laser and pulsed power fusion devices are critical for advancing high-energy-density physics, which "is a research hotspot in the frontier fields of national defense security and high-energy-density physics for powerful countries in science and technology."

How Pulsed Power Works

A pulsed power Z-pinch begins by storing a massive amount of electrical energy in an array of capacitor banks. Once these capacitors are fully charged, the stored energy is unleashed and delivered to a miniscule target within nanoseconds. The target material heats so fast that it first melts and then vaporizes, creating a plasma. This extremely high-current pulse creates a compressive magnetic force that squeezes ("pinches") the plasma inward. By compressing plasma to extreme temperatures and pressures, Z-pinches create miniature laboratory conditions that mimic those found in stars or nuclear explosions, making them a powerful tool for HEDP research and useful for military and civilian applications. In fact, pulsed power-driven ICF is seen as one of just a handful of promising approaches to realizing net-gain fusion energy sustainably and is a cornerstone of China's quest for commercial fusion.

A Deep Dive into China's Pulsed Power Facilities

Decades of pulsed power research in China have laid the foundation for the current buildout of advanced pulsed power infrastructure and created a robust ecosystem of research institutions and talent. China today manages a full pulsed power stack.

At the smaller end of the spectrum are flash-X accelerators that deliver bursts of less than one million amps, mainly used for laboratory radiation experiments. China also operates mid-sized machines like Qiangguang-1 and 2, which generate one to two million amps and enable different kinds of high-energy physics and materials research.

At the top stands Julong-1, a ten-million-amp Z-pinch device so powerful it can crush plasma with magnetic fields, a capability that has vaulted China into the top ranks of global high-energy density physics research. Together, these machines give Chinese researchers a toolkit that is only second to that of the U.S. labs at Sandia and Los Alamos.

New projects underway, however, may position China to surpass the United States in overall pulsed power capabilities.

China has long had plans to develop increasingly powerful Z-pinch pulsed power for weapons effects testing and fusion ignition. The country's earlier advancements in pulsed power research[20] have enabled detailed investigations of plasma compression, radiation transport, and material resilience under extreme conditions. Historical breakthroughs in high-power pulsed systems, such as the Julong-1 Z-pinch test stand[21] have enabled today's scaled up capabilities and laid the foundation for China's future Julong-2 50 MA and Z-FFR plans.

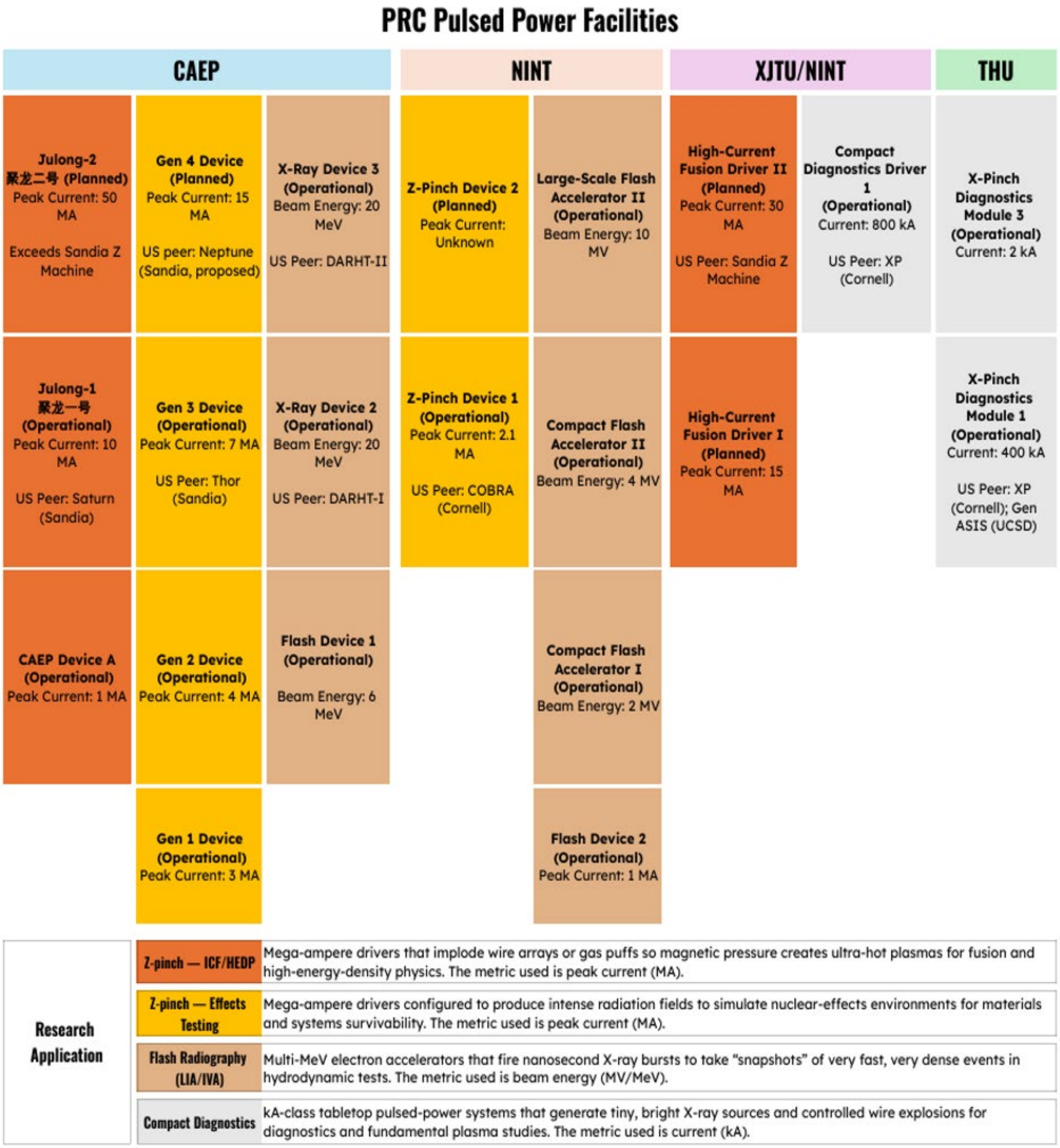
Julong-1, currently China's most powerful pulsed power facility, was completed[22] in 2012. The massive system—33 meters in diameter, 7 meters high—comprises 1,440 capacitors, 720 field-distortion switches, and other critical subsystems. Julong-1 successfully demonstrated peak currents of ~10 MA and x-ray yields up to 590 kJ, with peak x-ray powers exceeding 470 TW, placing it among the most advanced Z-pinch devices globally.

China's Julong-1 machine marked a breakthrough because, for the first time domestically in China, it produced star-like conditions—immense x-ray bursts and million-atmosphere pressures—giving Chinese scientists the ability to test nuclear physics and explore fusion energy in the lab without relying on underground nuclear tests.

Though significant, Julong-1 is still inferior to Sandia's Z machine in terms of peak current. But the CAEP, China's sole nuclear weapons research and production institution and under the direct administration of the PLA, has plans[23] to build Julong-2, the 50 MA device mentioned previously, which would surpass current U.S. capabilities.

FIGURE 7.

PRC Pulsed Power Facilities by Institution and Research Application



CAEP: China's Fusion Leader

As China's equivalent to Sandia or Los Alamos, CAEP plays a pivotal role in the nation's science and technology defense infrastructure while increasingly contributing to civilian applications, including nuclear fusion research.

Established in 1958 as the Beijing Ninth Research Institute under the Second Ministry of Machine Building, the institution underwent several transformations reflecting China's evolving nuclear ambitions and organizational priorities before officially adopting its current name—China Academy of Engineering Physics—for external use in 1985. Along with its name changes, CAEP's mission has evolved from its original nuclear weapons focus to encompass broader research domains, including shock wave and detonation physics, nuclear and plasma physics, computational physics, arms control-related physics, engineering mechanics, fluid dynamics, materials science, laser technology, and, notably, pulsed power technology and applications.

Dr. Peng Xianjue is one of the CAEP's most influential figures, leading pulsed power development and the main proponent of the Z-FFR approach to realizing commercial fusion. In 2008, Dr. Peng formally introduced the Z-FFR concept, which became a cornerstone of China's long-term fusion plans and was institutionalized with the inclusion of a 50 MA Z-pinch driver device in the 14th Five-Year Plan in 2021.

Today, CAEP stands as the institutional backbone of China's pulsed power capabilities and is undergoing[24] a massive expansion as China rapidly expands its nuclear arsenal and work in fusion energy. Dr. Deng Jianjun, another key Chinese fusion research scientist, leads the plasma physics division at CAEP and is overseeing the Julong-2 project. From its headquarters in Mianyang, Sichuan Province, CAEP operates China's most complete ladder of pulsed power hardware, a sequence of machines that escalates from single-shot flash-radiography sources to multi-MA Z-pinch drivers.

CAEP's Institute of Fluid Physics (IFP) was the earliest institution in China to engage in pulsed power research, covering areas such as the development of high-power switches, linear induction accelerators, facilities for Z-pinch studies, pulsed x-ray machines, explosive magnetic compression technology, rep-rate pulsed power generation, and time-resolved diagnostic technology. These devices all serve the dual purpose of advancing Chinese nuclear weapons and civilian scientific and engineering goals.

Other institutions also play key roles in China's pulsed power fusion efforts. In Shaanxi province, the Northwest Institute of Nuclear Technology (NINT) focuses on intense pulsed radiation environments for nuclear effects testing. Also in Shaanxi, the Xi'an Jiaotong University (XJTU) is another key pillar in China's pulsed power research. It houses a network[25] of interconnected schools, research institutes, and specialized centers, such as the School of Electrical Engineering, which designates "pulsed power and plasma technology" as one of its major research areas. Dr. Qiu Aici (邱爱慈) is recognized as another leading architect of China's modern pulsed power ecosystem, having led landmark accelerator programs at NINT and later XJTU. She is also an expert on high-altitude electromagnetic pulse weapons physics and defensive systems.

Beijing's Tsinghua University also specializes in pulsed power research through its Institute of High Voltage and Insulation Technology. Many of these institutions all collaborate with each other, including with CAEP, on various national programs and projects.

Industrial Applications of Pulsed Power

China's pulsed power technology has also rapidly extended into industrial domains, especially in energy, manufacturing, agriculture, and biomedical sectors. In the automotive and battery sectors, pulsed power is central to electromagnetic pulse forming and welding (EMPT) systems that use 100–300 kA of current to join aluminum, copper, and mixed-metal parts without heating.

Such systems are being deployed by BYD (比亚迪) suppliers and companies like Huashun Intelligent Equipment Co. (华舜智能装备有限公司), which produces 3–10 MJ EMPT lines for gigafactory production. Food and beverage producers increasingly rely on high-voltage pulsed electric field (PEF) sterilization, which applies 20–40 kV/cm, 1–10 µs pulses at kilohertz rates. These generate multi-megawatt instantaneous power inside the chamber, allowing for cold pasteurization of juices, dairy, and other liquids while preserving nutrients. Domestic studies show[26] bacterial inactivation with over 70 percent retention of green-tea polyphenols, with companies adopting systems codeveloped by academic labs and commercial food-processing vendors.

Resource and environmental sectors are also leveraging pulsed power systems. Aquaculture farms use 1 MA-class PEF modules to sterilize water and eliminate blue-green algae without chemicals, while electro-pulse reservoir stimulation systems developed by researchers at China University of Petroleum, East China (中国石油大学(华东) have been tested in Shanxi coal-bed methane wells.

These electric-pulse systems use ultra-short, high-voltage bursts to crack rock using electrical breakdown and the shock waves that follow. Lab[27] and modeling[28] studies of electro-pulse drilling show that fracture size and pattern are largely determined by pulse magnitude. Further experimentation to fine tune these settings can raise rock-breaking efficiency and cut energy use—quietly powering welding presses, sterilization lines, water treatment facilities, and even oilfield stimulation trucks across China.

Towards Commercial Fusion: CAEP Long-Term Plans for Pulsed Power Fusion

Taking a step back, within China harnessing the power of the sun, or fusion energy, is seen as the holy grail of pulsed power applications. Scientists involved in China's Z-pinch program have said China's roadmap for Z-pinch fusion centers on[29] a design formally outlined by Dr. Peng Xianjue of CAEP in 2014. In his speeches and writings, Dr. Peng claims that the Z-FFR approach is the most cost-effective and practical approach to creating clean nuclear fusion compared to other technologies, and he also has the added benefit of producing fissile material. Peng's plan involves developing and commercializing[30] Z-FFR by 2035.

CAEP's Z-FFR proposal is innovative, combining a fusion driver based on a 50–70 MA Z-pinch pulsed power device with a subcritical fission blanket composed of uranium-238, capable of breeding fissile materials like uranium-233 and plutonium-239. The system's design leverages[31] high-energy neutrons produced by fusion to interact with the fission blanket, generating additional energy while converting fertile material into fissile isotopes. The subcritical nature of the fission blanket enhances operational safety by preventing a sustained chain reaction independent of the fusion process. The Z-FFR is expected to produce[32] 1.5 GJ of energy per pulse, with 20 percent released as x-rays, presenting challenges for shielding and energy management that are actively being addressed through advanced engineering.

FIGURE 8.
Dr. Peng Xianjue's roadmap to achieve China's fusion ambitions using Z-pinch hybrid fission-fusion technology.

China's Path to Commercial Fusion

Z-FFR concept published	Julong-1 commissioned	Julong-2 commissioned	Engineering Demo	Commercial Power
Dr. Peng Xianjue introduces the fusion-fission hybrid model based on pulsed power Z-pinch, prioritizing a sub-ignition fusion driver embedded in uranium blanket.	China's first modern Z-pinch driver comes online, giving China a platform to explore target coupling, plasma evolution, and component resilience.	CEAP commissions a 50-MA LTD Z-pinch to achieve ignition-relevant conditions, prove efficient target coupling, and generate design data for the engineering test reactor.	Build an integrated test reactor and run a high-rep pulsed-power driver to prove repeatable fusion bursts and a heat-producing blanket that multiplies the energy ~10x—establishing early economics	Launch a grid-connected pilot to demonstrate reliable power, a workable fuel cycle, and bankable costs—then begin broader deployment.
2008	2012	2028	2030–2040	2040+

FIGURE 9.
Support for Julong-2 and CZ-15 pulsed power facilities at different levels of the Chinese government. Central, provincial, and institutional planning converged around 2021, embedding both devices in China's Five-Year planning system.

Pulsed Power Facilities Featured in PRC Five-Year Plans

Central	2021	Julong-2 included in National 14th FYP for Science and Technology Infrastructure
	2023	Central government reiterates acceleration of Julong-2
Provincial	2020	Sichuan "New Infrastructure Action Plan" calls to include 50 MA project (Julong-2) in 14th FYP
	2021	Julong-2 formally included in Sichuan's 14th Provincial FYP; XJTU Z-Pinch Device formally included in Shaanxi's 14th Provincial FYP
Institutional	2021	XJTU Z-Princh Device included in XJTU's FYP (15 billion RMB)

In a September 2023 presentation at an international physics conference, CAEP publicly detailed its plans for the Julong-2 50 MA Z-pinch pulsed power test stand, a core component of the Z-FFR program. If the described site is completed and becomes fully operational, it would be significantly larger and more capable than the Z machine at Sandia, currently the world's largest system. It is designed to achieve a current output of 50 MA drive targets up to 1.5 GJ of fusion output. For reference, the Z machine only produces 30 MA. Each Julong-2 pulse is planned to release approximately 300 MJ as x-rays, simulating conditions suitable for extreme environment studies and nuclear explosion effects.

The system's objectives extend beyond validating the Z-FFR design. It provides a platform for studying deuterium-tritium ignition and sustained thermonuclear burn, which is crucial for hybrid fusion-fission system physics. Simultaneously, carefully segmented aspects of the system can support nuclear explosion effects simulations, advancing research into material resilience, weapons effects, and the survivability of systems under extreme conditions. This allows China to study weapons effects and lead in nuclear deterrence, while still advancing broad energy deployment.

Chinese research also links the Z-FFR program to broader applications, including the breeding of fissile materials in the system's uranium-238 blanket. Research highlights the dual-use potential of Z-pinch technology, featuring its relevance to nuclear survivability and resilience studies. Successful construction of the Julong-2 will mark a milestone in China's quest to commercialize fusion energy and conduct other advanced HEDP research.

Over the last decade, China's Z-FFR efforts have made significant progress. After Dr. Peng published his seminal academic paper outlining the feasibility of Z-FFR, CAEP quickly began to publicly promote the idea to senior Chinese military and political leaders at events and in the media.

In 2018, Chinese nuclear physicists from multiple leading research institutes, including Dr. Peng, published a paper[33] that outlined what would later become the Chinese government's official nuclear energy and fusion official technology roadmap, stating:

> Z-pinch has greater potential as an energy source, and the Z-FFR proposed by China is more likely to be developed into a competitive future energy source. No shortcuts have been found to realize the application of fusion energy, but we need to continue to pay attention to new ideas, new technologies and new approaches in international fusion energy research.

The same year, Dr. Peng and other Chinese scientists also published a paper[34] in 2018 that asserted China has made significant progress in Z-pinch plasma research, including plasma implosion dynamics and radiation source physics, with notable advancements in the Z-FFR conceptual design. However, they noted key issues such as energy conversion efficiency and scaling laws for radiation sources remain underexplored. The paper suggested plans to develop a 50–70 MA Z-pinch driver by 2025 and pursue fusion ignition and hybrid power system engineering demonstrations by 2035.

A commercial network is growing around China's state-driven fusion energy technology development efforts. Dr. Peng currently runs two pulsed power fusion companies: Beijing-based Anton Fusion and Sichuan-based Xianjue Fusion. He also leads a Chengdu-based fusion-oriented nonprofit aimed at promoting pulsed power fusion. While details on the activities of these entities are sparse, Anton Fusion's corporate filings describe it as "focused on the industrialization of the core technology for Z-pinch-driven fusion-fission hybrid reactors (Z-FFR) for commercial power generation."

These companies' incorporation suggests that China is seeking to make fusion not only a state-led strategic project but also an emerging commercial sector, signaling a push to translate military-linked research into potential energy markets and industrial applications.

It now also appears that China is moving from ambition to action. CAEP's Julong-2 project was officially incorporated[35] into the 14th Five-Year Plan, and local governments in Sichuan and Chengdu have both granted preliminary regulatory approvals for the construction of a new Z-pinch facility for CAEP in or around Chengdu. There is also a significant amount of construction underway at CAEP's main campus in Mianyang.

Satellite imagery and local government procurement documents show construction underway in these areas, potentially for a large pulsed power device. Chengdu or another area around CAEP's main campus in Mianyang, Sichuan, could in fact be the location of the Julong-2 device. When completed, Julong-2 would represent a midway step in China's ambition to realize Z-FFR ambitions, providing the experimental platform needed to verify key technological concepts.

Other Chinese pulsed power efforts are also advancing quickly. At XJTU in western China, Z-pinch research is being driven forward[36] by Dr. Qiu Aici's team. XJTU has begun construction on two new pulsed power facilities that will range between 10 and 30 MA. These efforts by XJTU will not lead to high-gain fusion directly, but they will support CAEP's efforts by validating key technologies, highlighting how institutions across China are contributing to the nation's fusion ambitions with a wide range of new scientific infrastructure.

China's Direction and Potential U.S. Responses

China's advancements in pulse power for weapons science and fusion energy are approaching parity with legacy leaders in the field. More importantly, the Chinese state clearly recognizes the importance of pulsed power and has incorporated advancements in this field into national plans. Given the extensive and steady support the state has already provided (without requiring near-term returns), it is feasible that China could by the end of this decade take the lead in implementing pulsed power fusion in defense or industry applications.

Leading figures in China's nuclear research ecosystem, including pulsed power's biggest champion, Peng, are well equipped to advance China's capabilities. China's state planners and top nuclear scientists have reached a consensus regarding the critical potential of pulsed power; in a testament to their shared faith in the field, they are cooperating on research projects such as the 50 MA test stand and Z-pinch devices.

If successfully carried out, these programs stand to propel China ahead of the United States. As experts from both countries understand, whoever takes the lead in fusion stands to enjoy significant economic and strategic benefits. The difference is China's government appears equally invested in the effort—and willing to back its enthusiasm with financial and regulatory support.

Chinese leadership in advanced fusion and pulsed power fusion technology is not a given, however. The United States has a burgeoning[37] private sector, multiple companies of which are trying to commercialize inertial fusion technologies based on work done by the NIF and Z machine.

In a world where the United States is already well behind—it has not started on facilities to compete with what China is actively building—novel approaches may be required. For example, the U.S. government can explore milestone-based public-private partnerships[38] to take advantage of the private sector systems already being designed or under construction, if they could be adjusted to support a national security mission alongside commercial deployment. These facilities could become operational on the same timescale as the Chinese government projects discussed earlier.

The U.S. private sector serves as a uniquely American response to compete with China's state-based approach to leading in fusion's national security applications. The challenge lies in mobilizing and sustaining the necessary political will.

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