

China's Compact Fusion Pursuit: FRC Research, Microelectronics, and the Military-Civil Fusion Strategy

*An Open-Source Intelligence Investigation into China's Field-
Reversed Configuration Research Program, Semiconductor Crash
Program, and Plasma Weapons Development Pathway*

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This report examines China's pursuit of compact fusion technology through Field-Reversed Configuration (FRC) research, its military-civil fusion strategy, and the intersection of plasma physics with semiconductor and hypersonic weapons programs.

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Abstract & Methodology

Abstract

This report presents the findings of an open-source intelligence (OSINT) investigation into China's plasma physics research and directed energy weapons ecosystem. Drawing upon a network graph of 101 entities and 224 relationships, the investigation traces the connections between China's indigenous Field-Reversed Configuration (FRC) and spheromak research programs, the SIOM ball lightning soliton breakthrough, the Harbin Institute of Technology's plasmoid control experiments, the EAST and HL-3 tokamak programs, and the Military-Civil Fusion (MCF) policy framework that bridges civilian research and military applications. The central finding is more nuanced than a simple assessment of capability: no confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern that began with Soviet plasmoid research in the 1950s–60s.

The investigation identifies several distinct Chinese plasma-related efforts, each requiring a different confidence assessment under the V2 framework. The first is the **NUDT spheromak program** (Established), published in Systems Engineering and Electronics in January 2024 (DOI 10.12305/j.issn.1001-506X.2024.01.30). The National University of Defense Technology demonstrated a coaxial gun spheromak operating at 20 kV and 350 microfarads, achieving projectile velocities of approximately 1,000 km/s with electron densities on the order of 10 to the power of 16 per cubic centimeter. The paper explicitly describes the application as "remote magnetic control of space targets" — making China the only nation besides the United States with a published, peer-reviewed spheromak program explicitly oriented toward space warfare applications. Critically, the NUDT spheromak research directly references the US MARAUDER program, connecting China's effort to the American weapons lineage and placing it within the 66-year global plasma weapons interest pattern that began with Soviet plasmoid research in the 1950s–60s.

The second is the **SIOM ball lightning soliton experiment** (Established with critical limitation), published in Nature Photonics in April 2026 (DOI 10.1038/s41566-026-01899-y). The Shanghai Institute of Optics and Fine Mechanics, using the SULF (Shanghai Superintense-Ultrafast Lasers Facility) and Xihe 10-petawatt laser, achieved the first experimental demonstration of ball lightning as an electromagnetic soliton — a self-confined plasma structure sustained by its own electromagnetic fields. This is a landmark physics

result that represents physics validation relevant to weapons concepts, demonstrating that self-confined plasma structures can exist without external confinement — a property with profound implications for any future plasma orb weapon. However, the experiment was conducted in an argon gas environment, not in atmospheric air. The soliton's survival in the nitrogen-oxygen mixture of the actual atmosphere remains unproven. This limitation is critical and is examined in detail in Chapter 3.

The third is the **HIT plasmoid control program** (Established), conducted at the Harbin Institute of Technology in collaboration with the A.F. Ioffe Physico-Technical Institute and the Petersburg Nuclear Physics Institute (PNP) in Gatchina, Russia. Publications from 2021 and 2022 demonstrated electromagnetic steering and gating of plasmoids in atmospheric conditions — the ability to direct and control compact toroidal plasma structures using applied magnetic and electric fields. This collaboration represents a documented Russia-China technology transfer pathway in plasma weapons-relevant research.

The fourth is China's **civilian fusion infrastructure** (Established), which provides the plasma physics foundation underlying any weapons program. The Huazhong University of Science and Technology (HUST) operates the HFRC (Hefei FRC) facility with a 0.8-meter radius, 4.2-meter length, and 0.5 Tesla magnetic field achieved in 50 microseconds. The University of Science and Technology of China (USTC) operates the KTX (Keda Torus eXperiment) with FPGA-based feedback control at 25 kHz and under 50 microseconds latency. The EAST tokamak at ASIPP achieved a world-record 1,066-second H-mode plasma discharge in January 2025. The HL-3 tokamak achieved ion and electron temperatures exceeding 100 million degrees Celsius in 2025. China's total fusion investment is estimated at approximately 10 billion dollars, with an EMP research budget of 95 billion yuan (approximately 650 million dollars) for fiscal years 2024 through 2028.

The fifth is the **PLA and defense-industrial interest in plasma weapons** (Established as statements and programs). A PLA Daily article on July 26, 2019 explicitly discussed plasma weapons as "new concept weapons" — making China's interest in plasma weapons explicitly documented in official military doctrine. The China Aerospace Science and Technology Corporation (CASC) achieved a 100-kilowatt magnetoplasmadynamic thruster (MPDT) breakthrough in March 2025 and has fielded high-power microwave (HPM) systems. These statements and programs establish institutional interest and directed energy capabilities with explicit military intent, placing China as the newest entrant in the 66-year global plasma weapons interest pattern.

Key Finding (V2 Confidence Framework): No confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern. Every component exists in the open-source record: spheromak generation (NUDT, directly referencing MARAUDER), plasmoid electromagnetic steering (HIT), high-power microwave systems (CASC), ball lightning physics (SIOM, representing physics validation relevant to weapons concepts), and the fusion research infrastructure (HUST, USTC, EAST, HL-3). The Military-Civil Fusion policy provides the institutional bridge between civilian research and military application. No testing against satellites, no combat use, and no space-based plasma weapons have been documented. The existence of all components (Strongly inferred) does not establish the existence of a coordinated weapons program that integrates them. The full technology chain assessment is categorized as Strongly inferred, not Established.

Methodology

V2 Confidence Framework

This investigation employs a structured confidence framework that categorizes every claim according to the quality and quantity of supporting evidence. The framework defines five confidence levels:

- **Established:** Supported by primary sources — peer-reviewed publications, DOI-verified papers, government testimony, officially confirmed deployment statements, or documented experimental results.
- **Strongly inferred:** Supported by multiple converging lines of evidence but not directly confirmed by primary sources. The existence of all components of a technology chain, for example, strongly infers the capability to integrate them, even without direct confirmation of integration.
- **Plausible physics:** Consistent with known physics but not demonstrated at weapons scale or under operational conditions.
- **Speculation:** Not supported by direct evidence; based on extrapolation, analogy, or assumption.
- **Unsupported:** No experimental or theoretical support in the open-source record.

This framework replaces the earlier "high/medium/low confidence" schema and provides a more rigorous basis for distinguishing between what is known, what is inferred, what is physically plausible, and what remains speculative. The application of this framework to the China case has produced significant corrections to prior assessments, particularly regarding the distinction between possessing a complete technology chain and possessing an operational weapons system.

Source Corpus

The investigation draws upon a corpus of primary and secondary source documents spanning China's plasma physics and directed energy research, comprising:

- **NUDT spheromak publication (Established):** The January 2024 paper in Systems Engineering and Electronics (DOI 10.12305/j.issn.1001-506X.2024.01.30), documenting the coaxial gun spheromak operating at 20 kV and 350 microfarads, achieving approximately 1,000 km/s velocity and electron densities on the order of 10 to the power of 16 per cubic centimeter, with explicit application to "remote magnetic control of space targets."
- **SIOM ball lightning soliton publication (Established with limitation):** The April 2026 Nature Photonics paper (DOI 10.1038/s41566-026-01899-y), documenting the first experimental demonstration of ball lightning as an electromagnetic soliton using the SULF/Xihe 10-petawatt laser, conducted in argon gas.
- **HIT plasmoid control publications (Established):** 2021 and 2022 papers from the Harbin Institute of Technology, in collaboration with the A.F. Ioffe Physico-Technical Institute and PN Gatchina, documenting electromagnetic steering and gating of plasmoids in atmospheric conditions.
- **HUST HFRC facility documentation (Established):** Published specifications for the HFRC facility — 0.8-meter radius, 4.2-meter length, 0.5 Tesla magnetic field in 50 microseconds.
- **USTC KTX feedback control publications (Established):** Documentation of FPGA-based 25 kHz feedback control with under 50 microseconds latency on the Keda Torus eXperiment.
- **EAST tokamak records (Established):** The January 2025 world-record 1,066-second H-mode plasma discharge at ASIPP, Hefei.
- **HL-3 tokamak records (Established):** 2025 achievement of ion and electron temperatures exceeding 100 million degrees Celsius.

- **PLA Daily article (Established as statement):** The July 26, 2019 PLA Daily article discussing plasma weapons as "new concept weapons."
- **CASC HPM and MPDT documentation (Established):** The March 2025 100-kilowatt MPDT breakthrough and fielded high-power microwave systems.
- **Government policy documents (Established):** Military-Civil Fusion policy statements, fusion investment data, and EMP research budget allocations.
- **International reference framework (Established):** Chinese publications citing TAE Technologies C-2W, Nihon University FAT-CM, LANL FRCHX, and TRINITY plasmoid research — establishing the scientific foundation upon which Chinese research is built.

Analytical Framework

The investigation employed a structured OSINT methodology with the following components:

1. **Network Construction:** Extracted entities and relationships were used to construct a knowledge graph of 101 nodes and 224 edges, representing the interconnected ecosystem of Chinese universities, national laboratories, defense contractors, programs, technologies, and key personnel.
2. **Technology Chain Analysis:** The complete plasma weapons technology chain was mapped — spheromak generation, plasmoid steering, high-power microwave systems, ball lightning physics, fusion infrastructure — and each component was assessed for confidence level using the V2 framework.
3. **Cross-National Comparison:** Chinese plasma physics developments were compared against the US MARAUDER program (1988–1993), the Russian Stupitskiy plasmoid research, and the Russian Avramenko weapon claims to establish relative capability assessments and identify technology transfer pathways, including the documented HIT-PINP Gatchina collaboration.
4. **Source Verification and Confidence Categorization:** All claims are traced to specific source documents and categorized using the V2 confidence framework. Where claims rest on institutional statements rather than experimental results, this is explicitly noted. The investigation does not claim access to classified Chinese information; rather, it synthesizes the substantial body of openly published material — and rigorously distinguishes between what that material establishes and what it merely suggests.

Key Corrections from Prior Assessment

V2 Framework Corrections: This revised assessment corrects several significant errors in prior versions of this paper:

- 1. The technology chain is complete, but the weapons program is not confirmed.** Prior versions implied that the existence of all technology chain components established the existence of a coordinated weapons program. The V2 framework categorizes the full technology chain as Strongly inferred, not Established. No open-source evidence confirms a coordinated plasma weapons program that integrates all components.
- 2. The SIOM ball lightning soliton has a critical atmospheric limitation.** The Nature Photonics experiment was conducted in argon gas, not atmospheric air. The soliton's survival in the nitrogen-oxygen mixture of the actual atmosphere is unproven. Prior versions did not adequately emphasize this limitation.
- 3. No confirmed fielded operational plasma orb weapon, but a complete component-level technology chain with explicit military intent.** Prior versions implied or stated that China had deployed plasma weapons. The corrected assessment finds no confirmed fielded operational plasma orb weapon, but establishes that China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern — no testing against satellites, no combat use, no space-based plasma weapons.
- 4. The MH370 "Rosetta Stone" hypothesis has been removed.** Prior versions contained extensive speculative analysis contingent on the unverified MH370 hypothesis. This speculative content has been removed from the paper. The assessment of China's plasma weapons capability does not depend on the MH370 speculation.

Scope and Structure

This paper is organized into three substantive chapters following this abstract. Chapter 1 examines China's FRC research foundation, including the NUDT spheromak program, the HUST HFRC facility, the USTC KTX feedback control system, the EAST and HL-3 tokamak records, and the broader civilian fusion investment that underpins the plasma physics capability base. Chapter 2 analyzes the Military-Civil Fusion policy framework and the weapons development pathway, including the NUDT spheromak's explicit space-target

application, the HIT plasmoid control experiments, the PLA's "new concept weapons" statements, and the CASC high-power microwave and MPDT programs. Chapter 3 examines the SIOM ball lightning soliton experiment in detail, including the THz emission physics, the critical atmospheric limitation, and the implications for plasma weapons development. The conclusions chapter synthesizes these findings into an overall assessment using the V2 confidence framework.

Chapter 1: The FRC Research Foundation

1. The FRC Research Foundation

China's plasma weapons capability rests upon a foundation of indigenous Field-Reversed Configuration (FRC) and spheromak physics research, supported by a network of universities, national laboratories, and government funding bodies. Unlike the United States, where FRC research is distributed across national laboratories (LANL, AFRL, PPPL) and private companies (TAE Technologies, Helion Energy), China's program is concentrated in a smaller number of institutions with explicit state coordination through the Ministry of Science and Technology (MOST) and the National Natural Science Foundation of China (NSFC). China represents the newest entrant in the 66-year global plasma weapons interest pattern that began with Soviet plasmoid research in the 1950s–60s, continued through the US MARAUDER program (1988–1993), and extended through Russian Stupitskiy research (2019–2020). This chapter examines the key institutions, facilities, and experimental results that constitute China's plasma physics research foundation, with each claim categorized according to the V2 confidence framework.

1.1 The NUDT Spheromak Program (Established)

The National University of Defense Technology (NUDT), the PLA's premier defense research university, published a spheromak research program in Systems Engineering and Electronics in January 2024 (DOI 10.12305/j.issn.1001-506X.2024.01.30). This publication is of exceptional significance: it represents the only published, peer-reviewed spheromak program outside the United States that explicitly describes an application to "remote magnetic control of space targets." The paper documents a coaxial gun spheromak — a compact toroidal plasma device formed and accelerated using a coaxial plasma gun — with the following established parameters:

Parameter	NUDT Value	Confidence
Capacitor bank voltage	20 kV	Established
Capacitor bank capacitance	350 microfarads	Established
Projectile velocity	approximately 1,000 km/s	Established

Parameter	NUDT Value	Confidence
Electron density	on the order of 10 to the power of 16 per cubic centimeter	Established
Stated application	"Remote magnetic control of space targets"	Established

The NUDT spheromak is directly connected to two international programs: the US MARAUDER program (1988–1993) at Phillips Laboratory, which used a coaxial gun to accelerate compact toroids at extremely high velocities for weapons applications, and the Russian Stupitskiy plasmoid research at the Institute of Applied Physics (IAP), which explicitly referenced the MARAUDER experiments in developing compact toroid accelerators for potential orbital anti-satellite applications. Critically, the NUDT spheromak research directly references MARAUDER, connecting China's effort to the US weapons lineage and placing it within the 66-year global plasma weapons interest pattern. The NUDT program represents a Chinese extension of this lineage — a coaxial gun spheromak with explicit space warfare orientation.

Key Finding (Established): The NUDT spheromak program, published in Systems Engineering and Electronics (January 2024, DOI 10.12305/j.issn.1001-506X.2024.01.30), is the only published, peer-reviewed spheromak program outside the United States explicitly oriented toward "remote magnetic control of space targets." The coaxial gun operates at 20 kV and 350 microfarads, achieving approximately 1,000 km/s velocity with electron densities on the order of 10 to the power of 16 per cubic centimeter. The NUDT research directly references the US MARAUDER program, connecting China's effort to the American weapons lineage and placing it within the 66-year global plasma weapons interest pattern.

1.2 HUST HFRC Facility (Established)

The Huazhong University of Science and Technology (HUST) operates the HFRC (Hefei FRC) facility — China's most advanced dedicated FRC research device. The facility's established specifications are as follows:

Parameter	HFRC Value	Confidence
Radius	0.8 meters	Established
Length	4.2 meters	Established
Magnetic field	0.5 Tesla	Established

Parameter	HFRC Value	Confidence
Pulse duration	50 microseconds	Established

The HFRC facility is a civilian fusion research device, not a weapons platform. Its stated purpose is the study of Field-Reversed Configuration plasma physics for fusion energy applications. However, the plasma physics capabilities developed at HUST — FRC formation, magnetic confinement, plasma diagnostics — are directly transferable to weapons configurations through the Military-Civil Fusion policy framework examined in Chapter 2. The 0.5 Tesla magnetic field achieved in 50 microseconds represents a significant pulsed-power capability, and the 0.8-meter radius is sufficient for FRC formation and manipulation experiments relevant to both fusion and weapons applications.

The HFRC facility employs formation techniques that reference the international FRC research literature, particularly the TAE Technologies C-2W results and the Nihon University FAT-CM collisional merging experiments. This reference framework establishes a documented technology pathway from international civilian FRC research to China's indigenous program.

1.3 USTC KTX Feedback Control (Established)

The University of Science and Technology of China (USTC) operates the KTX (Keda Torus eXperiment) — a reversed-field pinch / FRC hybrid device that has achieved a significant milestone in real-time plasma control. The KTX employs FPGA-based feedback control operating at 25 kHz with a latency under 50 microseconds. This capability is directly relevant to plasma weapons applications, where the ability to rapidly sense and correct plasma instabilities determines whether a compact toroid can be maintained, steered, and projected over useful distances.

The 25 kHz feedback frequency and under 50 microsecond latency represent the state of the art in real-time plasma control. For comparison, the US MARAUDER program required sub-millisecond control of compact toroid formation and acceleration — a capability that the KTX feedback system exceeds by an order of magnitude. While the KTX is a civilian research device, the feedback control technology it demonstrates is a critical enabling capability for any weapons system that requires real-time stabilization of a compact toroidal plasma.

Technical Significance: Real-time feedback control of plasma configurations is one of the most critical enabling technologies for plasma weapons. A compact toroid that cannot be stabilized in real time will disintegrate before it can be projected to a target. The USTC KTX's 25 kHz FPGA-based feedback with under 50 microsecond latency represents a demonstrated capability in this critical technology domain — though demonstrated on a civilian research device, not a weapons platform.

1.4 EAST Tokamak — World Record (Established)

The Experimental Advanced Superconducting Tokamak (EAST), operated by the CAS Institute of Plasma Physics (ASIPP) in Hefei, achieved a world-record 1,066-second H-mode plasma discharge in January 2025. This is the longest sustained high-confinement plasma discharge ever achieved in any tokamak facility worldwide. The EAST record demonstrates China's capability in sustained plasma confinement — a capability that, while developed for civilian fusion energy, has direct relevance to the long-duration plasma confinement required for any weapons system that must maintain a plasma configuration over extended periods.

EAST is the world's first fully superconducting tokamak, and its achievements extend beyond the 1,066-second record to include sustained high-confinement (H-mode) operation, high-beta plasma regimes, and advanced divertor configurations. The superconducting magnet technology, plasma heating systems, and diagnostic suite developed for EAST are directly transferable to compact fusion and FRC research through the Military-Civil Fusion framework.

1.5 HL-3 Tokamak — Extreme Temperatures (Established)

The HL-3 tokamak, operated by the Southwestern Institute of Physics (SWIP) in Chengdu, achieved ion and electron temperatures exceeding 100 million degrees Celsius in 2025. This temperature — approximately seven times the temperature of the sun's core — is in the regime required for deuterium-tritium fusion reactions. While the HL-3 is a civilian fusion research device, the achievement demonstrates China's capability in generating and confining plasmas at fusion-relevant temperatures.

The HL-3 result complements the EAST long-duration record: EAST demonstrates sustained confinement, while HL-3 demonstrates extreme temperature capability. Together, these two facilities establish that China can generate, heat, and confine plasmas at the parameters required for both fusion energy and weapons-relevant plasma physics.

1.6 Civilian Fusion Investment (Established)

China's fusion research is supported by massive state investment. The total fusion investment is estimated at approximately 10 billion dollars, spanning tokamak research (EAST, HL-3, CFETR), FRC research (HUST HFRC, USTC KTX), laser fusion (SIOM), and alternative confinement concepts. In addition to the fusion budget, China has allocated an EMP research budget of 95 billion yuan (approximately 650 million dollars) for fiscal years 2024 through 2028. This EMP research budget is directly relevant to the plasma weapons pathway, as electromagnetic pulse effects are a primary kill mechanism of plasma-based directed energy weapons.

The scale of this investment is significant in comparative perspective. China's approximately 10 billion dollars in fusion investment exceeds the fusion budgets of most individual Western nations, though it remains below the combined US public-private fusion investment. The EMP research allocation of approximately 650 million dollars over five years represents a focused investment in the electromagnetic weapons domain that has no direct parallel in the Western research ecosystem.

1.7 International Reference Framework (Established)

China's FRC research program is explicitly built upon a framework of international scientific references. The following references appear repeatedly in Chinese FRC publications, establishing the scientific foundation upon which the indigenous program is constructed:

- **TAE Technologies C-2W (Established):** The primary reference for collisional merging FRC formation and sustained FRC parameters. TAE's published results provide the benchmark against which Chinese FRC research is measured. The HUST HFRC facility's formation techniques directly reference the C-2W approach.
- **Nihon University FAT-CM (Established):** The Field-reversed configuration Amalgamation eXperiment - Collisional Merging device at Nihon University represents the Japanese contribution to collisional merging FRC research. Chinese researchers reference FAT-CM publications as validation of the merging formation technique.
- **LANL FRCHX (Established):** The Field-Reversed Configuration Heating eXperiment at Los Alamos National Laboratory provides the reference for FRC heating and compression techniques relevant to Chinese FRC research.
- **TRINITI Plasmoid (Established):** The Russian TRINITI plasmoid research provides the reference for compact toroid acceleration and projection — capabilities with direct weapons applications. The NUDT spheromak program is comparable to and references this lineage of research.

Key Finding (Established): China's FRC research foundation is not built from scratch but is systematically constructed upon four international reference programs: TAE C-2W (formation), Nihon FAT-CM (merging validation), LANL FRCHX (heating/compression), and TRINITI Plasmoid (acceleration/projection). This reference framework covers the complete FRC technology chain from formation through to weapons-relevant acceleration. The NUDT spheromak program represents the indigenous extension of this framework into explicit space-target applications, directly referencing the US MARAUDER program and connecting China to the 66-year global plasma weapons interest pattern.

1.8 Enabling Technologies

The FRC research program is supported by a range of enabling technologies developed across multiple Chinese institutions:

1.8.1 Plasma Diagnostics Development

Advanced plasma diagnostics — Thomson scattering, interferometry, magnetic probing, neutron detection — are developed across ASIPP, SWIP, and HUST. These diagnostics are essential for characterizing FRC plasma parameters and validating computational models. The diagnostic capabilities developed for the EAST and HL-3 tokamak programs are directly transferable to FRC and spheromak research through the Military-Civil Fusion framework.

1.8.2 Computational Plasma Simulation

The Sunway Supercomputer, China's indigenous exascale computing platform, provides the computational power for large-scale plasma simulation. FRC plasma dynamics require magnetohydrodynamic (MHD) and kinetic simulations that are computationally intensive; access to the Sunway platform gives Chinese researchers simulation capabilities comparable to those at US national laboratories. Computational simulation is critical for weapons applications, where the behavior of compact toroids under acceleration, atmospheric transit, and target interaction must be modeled before experimental testing.

1.8.3 Superconducting Magnet Technology

Tsinghua University and Zhejiang University lead China's superconducting magnet technology development, producing the high-temperature superconducting (HTS) magnets required for compact fusion devices. The EAST tokamak's superconducting magnets represent a demonstrated capability in this domain. HTS magnets enable the compact form factor required for aerospace applications of plasma weapons systems.

1.9 Funding and Coordination

The FRC research program is funded and coordinated through several government mechanisms:

- **National Natural Science Foundation of China (NSFC):** The primary basic research funding body, providing grants for FRC physics, plasma diagnostics, and computational simulation research across Chinese universities and institutes.
- **Ministry of Science and Technology (MOST):** The central government body coordinating national science and technology programs, including the compact fusion research portfolio. MOST's coordination role is critical to the Military-Civil Fusion framework.
- **ITER Participation:** China is a founding member of the ITER international fusion collaboration, providing components and expertise in exchange for access to the global fusion research community.
- **CFETR (China Fusion Engineering Testing Reactor):** The domestic follow-on to ITER, representing China's commitment to an independent fusion energy pathway.
- **EMP Research Budget:** The 95 billion yuan (approximately 650 million dollars) allocation for fiscal years 2024 through 2028, directly relevant to electromagnetic weapons development.

Key Finding (Established): China's FRC research foundation is solid, well-funded, and comprehensive. The combination of the NUDT spheromak program (explicitly weapons-oriented, directly referencing MARAUDER), the HUST HFRC facility (0.8-meter radius, 0.5 Tesla), the USTC KTX feedback control (25 kHz, under 50 microseconds), the EAST world record (1,066 seconds H-mode), the HL-3 extreme temperatures (over 100 million degrees Celsius), and approximately 10 billion dollars in fusion investment provides a comprehensive research infrastructure. Every component of the plasma weapons technology chain has a demonstrated Chinese capability. However, the existence of these civilian capabilities (Established) does not establish the existence of a coordinated weapons program that integrates them (Strongly inferred at best). China represents the newest entrant in the 66-year global plasma weapons interest pattern.

Chapter 2: The Microelectronics Crash Program

2. Military-Civil Fusion and the Weapons Pathway

The Military-Civil Fusion (MCF) policy framework is the institutional architecture that bridges the civilian research examined in Chapter 1 with the defense-industrial base that develops and deploys weapons systems. MCF is not merely a policy directive; it is a structural reorganization of China's research and industrial ecosystem that systematically channels civilian capabilities into military applications under the direct authority of the Central Military Commission (CMC). This chapter examines the weapons development pathway — from the NUDT spheromak's explicit space-target application (directly referencing the US MARAUDER program), through the HIT plasmoid control experiments, to the PLA's explicitly documented institutional interest in plasma weapons ("new concept weapons") and the CASC directed energy programs — with each claim categorized according to the V2 confidence framework. Together, these elements establish China as the newest entrant in the 66-year global plasma weapons interest pattern.

2.1 Military-Civil Fusion (MCF) Policy (Established)

The Military-Civil Fusion policy, formally elevated to a national strategy in 2017, mandates the integration of civilian research institutions, universities, and industrial enterprises with the defense-industrial base. Under MCF, technologies developed for civilian applications — plasma physics, superconducting magnets, computational simulation, laser systems — are systematically transferred to defense programs through institutional coordination mechanisms. The CMC, chaired by Xi Jinping, exercises direct authority over this transfer process, ensuring that civilian research outputs are prioritized for military application according to defense requirements rather than civilian research priorities.

This top-down coordination model fundamentally differs from the Western approach, where technology transfer from civilian to military applications typically occurs through contractual mechanisms (DARPA programs, defense procurement) rather than through direct institutional authority. The MCF framework means that the civilian plasma physics capabilities documented in Chapter 1 — the NUDT spheromak, the HUST HFRC, the USTC KTX, the EAST and HL-3 tokamaks — are structurally available to the defense-industrial base without the barriers that separate civilian and military research in Western ecosystems.

2.2 The NUDT Spheromak: "Remote Magnetic Control of Space Targets" (Established)

The NUDT spheromak program, examined in Chapter 1 for its technical parameters, takes on its full significance in the Military-Civil Fusion context. The National University of Defense Technology is not a civilian institution — it is the PLA's premier defense research university, subordinate to the Central Military Commission. The publication of a spheromak program from NUDT with the explicit application description "remote magnetic control of space targets" represents the most direct open-source evidence of Chinese military interest in compact toroid weapons for space warfare.

The technical parameters — 20 kV, 350 microfarads, approximately 1,000 km/s, electron densities on the order of 10 to the power of 16 per cubic centimeter — are comparable to the US MARAUDER program's coaxial gun parameters. Critically, the NUDT spheromak research directly references MARAUDER, connecting China's effort to the US weapons lineage. The MARAUDER program, conducted at Phillips Laboratory from 1988 to 1993, accelerated compact toroids using a coaxial gun for aerodynamic disruption of targets. The NUDT program represents a direct Chinese extension of this lineage, with the critical distinction that the NUDT paper explicitly describes space-target applications, while the MARAUDER program's space applications remained classified.

Key Finding (Established): The NUDT spheromak program (Systems Engineering and Electronics, January 2024, DOI 10.12305/j.issn.1001-506X.2024.01.30) is the most direct open-source evidence of Chinese military interest in compact toroid weapons for space warfare. The program was published by the PLA's premier defense research university with the explicit application "remote magnetic control of space targets." The NUDT research directly references the US MARAUDER program, connecting China's effort to the American weapons lineage and the 66-year global plasma weapons interest pattern. This is not a civilian research program with weapons implications — it is a military research program with a stated space warfare application.

2.3 HIT Plasmoid Control Experiments (Established)

The Harbin Institute of Technology (HIT) has demonstrated electromagnetic steering and gating of plasmoids in atmospheric conditions — the ability to direct and control compact toroidal plasma structures using applied magnetic and electric fields. This capability was

documented in publications from 2021 and 2022, produced in collaboration with the A.F. Ioffe Physico-Technical Institute and the Petersburg Nuclear Physics Institute (PNP) in Gatchina, Russia.

The HIT plasmoid control experiments are significant for three reasons:

1. **Atmospheric operation (Established):** The experiments were conducted in atmospheric conditions — not in vacuum or controlled gas environments. This is critical because any plasma weapon intended for atmospheric use (ground-to-air, air-to-air, or ground-to-space intercept) must be able to generate and control plasmoids in the actual atmosphere. The HIT experiments demonstrate this capability.
2. **Electromagnetic steering (Established):** The experiments demonstrated the ability to steer plasmoids using applied electromagnetic fields — the fundamental capability required to direct a plasma weapon at a target. Without steering capability, a compact toroid would follow a ballistic trajectory and could not track a maneuvering target.
3. **Russia-China collaboration (Established):** The collaboration with the Ioffe Institute and PNP Gatchina represents a documented Russia-China technology transfer pathway in plasma weapons-relevant research. The Gatchina institute is the same institution that produced long-lived plasmoids in air with lifetimes of 500 to 600 milliseconds — a result directly relevant to plasma weapons development. The HIT-PNP collaboration ensures that Russian plasmoid expertise flows into the Chinese research ecosystem.

Russia-China Technology Transfer: The HIT-PNP Gatchina collaboration (2021–2022 publications) is one of the most significant documented technology transfer pathways in the plasma weapons domain. The Gatchina institute's plasmoid research — producing long-lived plasmoids in air with 500–600 millisecond lifetimes — represents the state of the art in atmospheric plasmoid generation. The collaboration ensures that this Russian expertise is integrated into the Chinese research program through the Harbin Institute of Technology, an institution with deep ties to China's defense-industrial base.

2.4 PLA "New Concept Weapons" Statement (Established as Statement)

On July 26, 2019, the PLA Daily — the official newspaper of the People's Liberation Army — published an article explicitly discussing plasma weapons as "new concept weapons." This article is of exceptional significance because it represents an explicit, official PLA acknowledgment of plasma weapons as a category of military interest — making China's

interest in plasma weapons explicitly documented in official military doctrine. The term "new concept weapons" (xin gainian wuqi) is used in Chinese military doctrine to describe weapons systems based on novel physical principles that are not yet fully operational — a category that includes directed energy weapons, electromagnetic pulse weapons, and plasma weapons.

The PLA Daily article does not confirm the existence of a fielded plasma weapons system. It establishes explicitly documented institutional interest and doctrinal attention. The distinction is critical: a military newspaper discussing a weapons category as a "new concept" is an acknowledgment of research interest, not a confirmation of operational capability. Under the V2 framework, this is categorized as Established (as a statement of institutional interest), not as Established (as a weapons system). However, the explicit documentation of plasma weapons interest in official PLA doctrine places China firmly within the 66-year global plasma weapons interest pattern — as the newest entrant with explicitly documented military intent.

2.5 CASC High-Power Microwave and MPDT Programs (Established)

The China Aerospace Science and Technology Corporation (CASC), China's primary state-owned aerospace and defense contractor, has achieved two significant milestones in directed energy and plasma propulsion technology:

2.5.1 100-Kilowatt MPDT Breakthrough (Established)

In March 2025, CASC achieved a 100-kilowatt magnetoplasmadynamic thruster (MPDT) breakthrough. The MPDT is a plasma propulsion device that uses the Lorentz force to accelerate plasma to high velocities — the same fundamental physics underlying compact toroid acceleration in weapons applications. A 100-kilowatt MPDT represents a significant power level for a plasma propulsion device, demonstrating CASC's capability in high-power plasma generation and acceleration.

While the MPDT is a propulsion device (for spacecraft propulsion, not weapons), the technology is directly transferable to weapons applications through the Military-Civil Fusion framework. The ability to generate and accelerate plasma at 100-kilowatt power levels is a prerequisite for any compact toroid weapons system — and CASC has demonstrated this capability.

2.5.2 Fielded High-Power Microwave Systems (Established)

CASC has fielded high-power microwave (HPM) systems — directed energy weapons that use intense microwave radiation to damage or destroy electronic systems. HPM systems are distinct from plasma orb weapons but are part of the same directed energy weapons ecosystem. The fielding of HPM systems by CASC establishes that China has operational directed energy weapons capability, even if the specific capability is microwave-based rather than plasma-based.

The significance of the HPM systems for the plasma weapons assessment is twofold: first, the pulsed-power technology underlying HPM systems (capacitor banks, switching systems, power conditioning) is directly applicable to compact toroid weapons; second, the electromagnetic pulse effect of HPM systems is one of the primary kill mechanisms of plasma-based directed energy weapons, which generate intense EMP effects when the plasma structure interacts with a target.

2.6 The Weapons Development Pathway (Strongly Inferred)

Based on the evidence assembled in this chapter and Chapter 1, the plasma weapons development pathway can be traced as follows:

Stage	Technology	Lead Institution	Confidence
1	Spheromak generation (coaxial gun)	NUDT	Established
2	Plasmoid electromagnetic steering	HIT (with PNP Gatchina)	Established
3	Real-time plasma feedback control	USTC (KTX)	Established
4	High-power plasma generation	CASC (100 kW MPDT)	Established
5	Directed energy systems fielded	CASC (HPM systems)	Established
6	Integration into coordinated weapons program	Unknown	Strongly inferred
7	Fielded operational plasma orb weapon	Unknown	Not established

Stages 1 through 5 are each Established — the individual technology components exist and are documented in the open-source record. Stage 6 — the integration of these components into a coordinated weapons program — is Strongly inferred: the existence of all components, combined with the Military-Civil Fusion policy that provides the institutional bridge between civilian research and military application, strongly suggests the capability to integrate them.

However, no open-source evidence confirms that such integration has occurred. Stage 7 — a fielded operational plasma orb weapon — is not established. No testing against satellites, no combat use, and no space-based plasma weapons have been documented in the open-source record.

Critical Distinction: The existence of a complete technology chain (Established) does not establish the existence of a coordinated weapons program (Strongly inferred) or a fielded operational weapon (not established). The V2 confidence framework requires rigorous distinction between possessing the components of a capability and possessing the integrated, operational capability itself. China possesses every component of the plasma weapons technology chain with explicit military intent (PLA "new concept weapons") — but no confirmed fielded operational plasma orb weapon. China represents the newest entrant in the 66-year global plasma weapons interest pattern.

2.7 Defense-Industrial Base

The defense-industrial base supporting the plasma weapons pathway comprises three major state-owned conglomerates:

- **CASC (China Aerospace Science and Technology Corporation):** Primary defense contractor for spacecraft, launch vehicles, and strategic weapons. CASC's 100-kilowatt MPDT breakthrough and fielded HPM systems establish its role as the primary directed energy weapons developer. CASC would be the likely integrator of any plasma weapons system, combining NUDT spheromak technology, HIT plasmoid control, and CASC pulsed-power capabilities.
- **CASIC (China Aerospace Science and Industry Corporation):** Defense contractor specializing in missile systems and defense electronics. CASIC's plasma-related research focuses on plasma stealth technology and hypersonic plasma sheath management — applications that utilize the same plasma physics capabilities as the weapons program but for platform survivability rather than offensive weapons.
- **AVIC (Aviation Industry Corporation of China):** State-owned aviation conglomerate. AVIC's plasma-related research focuses on plasma stealth applications for aircraft, paralleling CASIC's work but focused on airborne platforms.

2.8 The DF-17 and Hypersonic Plasma Sheath Research

The DF-17, a road-mobile medium-range ballistic missile system equipped with a hypersonic glide vehicle (HGV), was publicly revealed in 2019. The DF-17's HGV travels at hypersonic speeds through the atmosphere, generating a plasma sheath that envelops the vehicle. This plasma sheath is a byproduct of hypersonic atmospheric flight — not an offensive plasma weapon. It provides passive radar cross-section reduction as a natural consequence of the ionized flow field, similar to the Russian Avangard system.

The DF-17 is relevant to the plasma weapons assessment because it demonstrates China's operational experience with plasma physics in a weapons platform context. The plasma sheath management challenge — maintaining guidance and communication through an ionized envelope — requires the same plasma physics capabilities underlying the compact toroid weapons program. The CASIC and AVIC hypersonic plasma sheath research, supported by Military-Civil Fusion-coordinated transfer of plasma physics capabilities from ASIPP, SWIP, and HUST, provides the scientific foundation for managing this plasma environment.

2.9 Assessment of the Weapons Pathway

Key Finding (Strongly Inferred): No confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern. Every component exists in the open-source record: spheromak generation (NUDT, directly referencing MARAUDER, Established), plasmoid electromagnetic steering (HIT, Established), real-time plasma feedback control (USTC, Established), high-power plasma generation (CASC, Established), and fielded directed energy systems (CASC HPM, Established). The Military-Civil Fusion policy provides the institutional bridge for integration. The PLA Daily article establishes explicitly documented institutional interest. The full technology chain assessment is Strongly inferred — all components exist, but their integration into an operational weapons system is not confirmed.

Chapter 3: Military-Civil Fusion and the Weapons Pathway

3. SIOM and Ball Lightning Physics

The Shanghai Institute of Optics and Fine Mechanics (SIOM), a research institute of the Chinese Academy of Sciences, achieved a landmark result in plasma physics: the first experimental demonstration of ball lightning as an electromagnetic soliton. Published in *Nature Photonics* in April 2026 (DOI 10.1038/s41566-026-01899-y), this experiment represents a significant advance in the understanding of ball lightning — the mysterious phenomenon of luminous, spherical plasma objects that persist for seconds, defying conventional plasma physics expectations. While the experiment has a critical atmospheric limitation, it represents physics validation relevant to weapons concepts — demonstrating that self-confined plasma structures can exist without external confinement, a property with profound implications for any future plasma orb weapon. This chapter examines the SIOM experiment, its physics, and a critical limitation that has profound implications for any assessment of its weapons relevance.

3.1 The SIOM Ball Lightning Soliton Experiment (Established)

The SIOM experiment used the SULF (Shanghai Superintense-Ultrafast Lasers Facility) and the Xihe laser — a 10-petawatt ultrafast laser system — to create ball lightning in a controlled laboratory environment. The experiment achieved the first experimental demonstration of ball lightning as an electromagnetic soliton: a self-confined plasma structure sustained by its own electromagnetic fields, rather than by external confinement mechanisms such as magnetic coils or inertial compression.

The concept of ball lightning as an electromagnetic soliton is a theoretical proposal that has been discussed in the plasma physics literature for decades. A soliton is a self-reinforcing wave packet that maintains its shape while propagating at constant velocity — a nonlinear structure that is self-confined by the balance of dispersion and nonlinearity. In the context of ball lightning, the soliton hypothesis proposes that the luminous sphere is a self-confined electromagnetic plasma structure that persists because its internal electromagnetic fields provide the confinement that would otherwise require external magnets or walls.

The SIOM experiment is the first to demonstrate this hypothesis experimentally. Using the extreme intensity of the 10-petawatt laser, the SIOM team created a plasma configuration that self-organized into a stable, luminous sphere — a ball lightning soliton — that persisted for a measurable duration without external confinement. This is a landmark physics result with implications for plasma confinement, compact toroid physics, and the fundamental understanding of ball lightning.

Key Finding (Established): The SIOM ball lightning soliton experiment, published in Nature Photonics (April 2026, DOI 10.1038/s41566-026-01899-y), is the first experimental demonstration of ball lightning as an electromagnetic soliton. Using the SULF/Xihe 10-petawatt laser, the SIOM team created a self-confined plasma structure sustained by its own electromagnetic fields. This is a landmark physics result that validates the soliton hypothesis of ball lightning and demonstrates a new regime of plasma confinement — representing physics validation relevant to weapons concepts, as self-confined plasma structures are a prerequisite for any compact plasma orb weapon.

3.2 The SULF/Xihe Laser System (Established)

The SULF (Shanghai Superintense-Ultrafast Lasers Facility) and the Xihe laser represent China's entry into the petawatt-class laser regime. The Xihe laser, named after the ancient Chinese sun goddess, is a 10-petawatt ultrafast laser system — one of the most powerful lasers in the world. For comparison, the most powerful US laser systems (such as the National Ignition Facility's NIF-ARC and the Omega-EP at the University of Rochester) operate in the petawatt class, and the European ELI (Extreme Light Infrastructure) project targets multi-petawatt operation.

The 10-petawatt power level is significant for plasma weapons research because it enables the creation of plasma conditions that cannot be achieved with conventional pulsed-power systems. The extreme intensity of a petawatt-class laser creates plasma through direct ionization of the target material, and the resulting plasma can reach temperatures and densities that are relevant to both fusion and weapons applications. The SIOM ball lightning soliton experiment is one application of this capability; other potential applications include laser-driven compact toroid formation, laser-plasma acceleration, and laser-driven electromagnetic pulse generation.

3.3 THz Emission and Electromagnetic Effects (Established)

The SIOM experiment documented significant terahertz (THz) emission from the ball lightning soliton. THz radiation is a consequence of the nonlinear plasma dynamics within the soliton structure — the acceleration of charged particles within the self-confined electromagnetic field generates electromagnetic radiation in the terahertz frequency range. This THz emission is relevant to the weapons assessment because THz radiation is one of the mechanisms by which a plasma weapon could damage or disrupt electronic systems.

THz radiation can penetrate many materials that are opaque to visible and infrared light, including clothing, packaging, and some building materials. More significantly for weapons applications, THz radiation can couple into electronic circuits and disrupt their operation — a mechanism related to but distinct from the electromagnetic pulse (EMP) effect of conventional directed energy weapons. The observation of THz emission from the ball lightning soliton suggests that a plasma weapon based on soliton physics could produce electromagnetic effects beyond the simple kinetic or thermal damage mechanisms of conventional compact toroid weapons.

3.4 The Critical Atmospheric Limitation

Critical Limitation (Established): The SIOM ball lightning soliton was created in an argon gas environment, not in atmospheric air. The experiment used argon — a noble gas — as the medium in which the soliton formed and persisted. The soliton's survival in the nitrogen-oxygen mixture of the actual atmosphere has not been demonstrated and remains unproven. This limitation is critical for any assessment of the experiment's weapons relevance.

The distinction between argon and atmospheric air is not a minor technical detail — it is fundamental to the physics of the soliton and to any assessment of its weapons potential. The reasons are as follows:

1. **Chemical reactivity:** Argon is a noble gas — chemically inert, with no tendency to form molecular compounds or engage in chemical reactions with the plasma. Atmospheric air is approximately 78 percent nitrogen and 21 percent oxygen — both chemically reactive gases that form molecular compounds (NO, NO₂, O₃) when ionized. These molecular reactions can disrupt the electromagnetic field structure of the soliton, potentially causing it to disintegrate.
2. **Radiative losses:** In argon, the primary energy loss mechanism from the soliton is bremsstrahlung (braking radiation) from free electrons. In atmospheric air, additional

energy loss mechanisms include molecular rotational and vibrational excitation of nitrogen and oxygen molecules, which can significantly increase the rate of energy loss from the plasma. A soliton that is stable in argon may be unstable in air because the increased radiative losses exceed the electromagnetic self-confinement energy.

3. **Electron attachment:** In atmospheric air, free electrons can attach to oxygen molecules, forming negative ions (O_2^-). This electron attachment process depletes the free electron population that sustains the soliton's electromagnetic field. In argon, electron attachment does not occur because argon does not form negative ions. A soliton that persists in argon may dissipate in air because the electron population is depleted by attachment to oxygen.
4. **Ionization potential:** Argon has an ionization potential of 15.76 eV, compared to 14.53 eV for nitrogen and 13.62 eV for oxygen. The lower ionization potentials of atmospheric gases mean that the plasma behavior in air will differ from that in argon — the soliton's electromagnetic field structure, which depends on the ionization state of the gas, will be different in the two environments.

These four factors — chemical reactivity, radiative losses, electron attachment, and ionization potential — collectively mean that a ball lightning soliton that is stable in argon may not be stable in atmospheric air. The SIOM experiment demonstrates the soliton hypothesis in principle; it does not demonstrate that the soliton can survive in the atmosphere. This distinction is critical for the weapons assessment: a plasma weapon that only works in an argon environment has no military utility. A plasma weapon that works in atmospheric air would be a transformative capability.

Key Finding (Established with Limitation): The SIOM ball lightning soliton experiment is a landmark physics result — the first experimental demonstration of ball lightning as an electromagnetic soliton. However, the soliton was created in argon gas, not in atmospheric air. The soliton's survival in the nitrogen-oxygen mixture of the actual atmosphere is unproven. The chemical reactivity, radiative losses, electron attachment, and ionization potential differences between argon and air may prevent the soliton from persisting in atmospheric conditions. This limitation is critical for any assessment of the experiment's weapons relevance: a plasma weapon that only works in argon has no military utility.

3.5 Implications for the Weapons Assessment

The SIOM ball lightning soliton experiment has three implications for the overall assessment of China's plasma weapons capability:

First, it demonstrates a new plasma confinement regime — physics validation relevant to weapons concepts (Established). The soliton represents a fundamentally different approach to plasma confinement from the magnetic confinement (tokamaks, FRC) and inertial confinement (laser fusion) approaches that dominate fusion research. A self-confined plasma structure that does not require external magnets or walls could, in principle, enable a compact plasma weapon that does not require the bulky magnetic field hardware of conventional compact toroid weapons. This is a physics result with direct relevance to weapons concepts — the self-confinement mechanism is a prerequisite for any compact plasma orb weapon, and its experimental demonstration represents physics validation of a key weapons-enabling concept, even though the experiment was limited to argon gas.

Second, it demonstrates China's laser-plasma capability (Established). The 10-petawatt Xihe laser represents a significant capability in laser-driven plasma physics. This capability is relevant to multiple weapons-related applications beyond ball lightning, including laser-driven compact toroid formation, laser-plasma acceleration, and laser-driven EMP generation. The existence of this laser capability is an Established fact with weapons-relevant implications.

Third, it does not demonstrate an atmospheric plasma weapon (Not Established). The critical atmospheric limitation means that the SIOM experiment cannot be cited as evidence of an operational atmospheric plasma weapon. The soliton was created in argon, not in air. Until the soliton's atmospheric survival is demonstrated — or until an alternative approach to creating self-confined plasma structures in air is developed — the ball lightning soliton remains a physics result, not a weapons capability.

3.6 The Broader Ball Lightning Weapons Context

The concept of ball lightning as a weapons phenomenon has a long history in the plasma weapons literature. The US AFRL DPF paper (2006) described "pulsed-train plasmoid weapons" using dense plasma focus technology — a different approach to creating compact plasma structures, but with the same goal of projecting self-confined plasma at targets. The Russian Gatchina discharge experiments produced long-lived plasmoids in air with 500 to 600 millisecond lifetimes — demonstrating that long-lived plasma structures can exist in the actual atmosphere, though by a different mechanism than the SIOM soliton.

The SIOM experiment and the Gatchina experiments represent two different approaches to the same problem: creating a plasma structure that persists long enough to be useful as a weapon. The Gatchina approach uses electrical discharge in air to create plasmoids that persist through thermal and magnetic mechanisms. The SIOM approach uses laser-driven ionization in argon to create a soliton that persists through electromagnetic self-confinement.

Neither approach has yet demonstrated all the requirements for an operational weapon: the Gatchina plasmoids persist in air but have not been demonstrated at weapons-relevant velocities or with steering capability; the SIOM soliton demonstrates self-confinement but has not been demonstrated in air.

Comparative Assessment: The SIOM soliton and the Gatchina plasmoid represent complementary approaches to the atmospheric plasma weapon problem. The Gatchina approach solves the atmospheric survival problem but not the self-confinement problem. The SIOM approach solves the self-confinement problem but not the atmospheric survival problem. A weapon that combined both approaches — a self-confined soliton that can survive in atmospheric air — would represent a significant advance. No such combination has been demonstrated in the open-source record.

3.7 SIOM and the Military-Civil Fusion Framework

SIOM is a research institute of the Chinese Academy of Sciences — a civilian research organization. The ball lightning soliton experiment was published in *Nature Photonics*, an international peer-reviewed journal, as a fundamental physics result. There is no direct evidence in the open-source record that the SIOM soliton experiment was conducted with weapons applications in mind, or that the results have been transferred to a military program.

However, the Military-Civil Fusion policy framework means that SIOM's plasma physics capabilities — including the 10-petawatt Xihe laser and the ball lightning soliton physics — are structurally available to the defense-industrial base. The MCF framework does not require evidence of a specific transfer event; it establishes the institutional pathway through which transfer can occur. Under the V2 framework, the potential weapons application of the SIOM soliton physics is categorized as Plausible physics — consistent with known physics but not demonstrated at weapons scale or under operational conditions (specifically, not demonstrated in atmospheric air).

3.8 Assessment of the Ball Lightning Soliton

Key Finding (Established with Critical Limitation): The SIOM ball lightning soliton experiment (Nature Photonics, April 2026, DOI 10.1038/s41566-026-01899-y) is a landmark physics result — the first experimental demonstration of ball lightning as an electromagnetic soliton, representing physics validation relevant to weapons concepts. The experiment used the SULF/Xihe 10-petawatt laser and documented significant THz emission. However, the soliton was created in argon gas, not atmospheric air. The soliton's survival in the nitrogen-oxygen mixture of the actual atmosphere is unproven, and the chemical reactivity, radiative losses, electron attachment, and ionization potential differences between argon and air may prevent atmospheric survival. The weapons relevance of the SIOM soliton is categorized as Plausible physics — the self-confinement mechanism is demonstrated as physics validation, but its operation in atmospheric conditions is not.

Conclusions & Assessment

Conclusions & Assessment

The evidence assembled across three chapters establishes a clear and consequential finding: no confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern. This concluding chapter synthesizes the findings, presents the overall assessment using the V2 confidence framework, and identifies the implications for the global plasma weapons landscape.

The Complete Technology Chain (Strongly Inferred)

The most significant finding of this investigation is that China possesses every component of the plasma weapons technology chain. Each component is individually Established in the open-source record:

Component	Institution	Evidence	Confidence
Spheromak generation	NUDT	Systems Engineering and Electronics, Jan 2024 (DOI 10.12305/j.issn.1001-506X.2024.01.30)	Established
Plasmoid electromagnetic steering	HIT (with PNP Gatchina)	2021–2022 publications on EM steering/gating in atmosphere	Established
Real-time plasma feedback control	USTC	KTX FPGA-based 25 kHz feedback, under 50 microseconds latency	Established
FRC research infrastructure	HUST	HFRC facility: 0.8m radius, 4.2m length, 0.5T in 50 microseconds	Established
Sustained plasma confinement	ASIPP	EAST tokamak: 1,066s H-mode world record, Jan 2025	Established
Extreme temperature plasma	SWIP	HL-3 tokamak: over 100 million degrees Celsius, 2025	Established
Ball lightning soliton physics	SIOM	Nature Photonics, Apr 2026 (DOI 10.1038/s41566-026-01899-y)	Established (with limitation)

Component	Institution	Evidence	Confidence
High-power plasma generation	CASC	100 kW MPDT breakthrough, Mar 2025	Established
Fielded directed energy systems	CASC	Fielded HPM systems	Established
Institutional interest	PLA	PLA Daily article on plasma weapons, Jul 26, 2019	Established (as statement)
MCF coordination framework	CMC	Military-Civil Fusion policy, national strategy since 2017	Established

The existence of all these components, combined with the Military-Civil Fusion policy that provides the institutional bridge between civilian research and military application, strongly infers the capability to integrate them into a coordinated weapons program. However, the V2 confidence framework requires rigorous distinction between possessing the components of a capability and possessing the integrated, operational capability itself. The full technology chain assessment is therefore categorized as Strongly inferred, not Established.

V2 Confidence Framework Assessment

The findings of this investigation can be categorized by confidence level as follows:

Established

The following claims are supported by primary sources — peer-reviewed publications, DOI-verified papers, government statements, or documented experimental results:

- **NUDT spheromak program:** Published in *Systems Engineering and Electronics* (January 2024, DOI 10.12305/j.issn.1001-506X.2024.01.30). Coaxial gun, 20 kV, 350 microfarads, approximately 1,000 km/s, electron densities on the order of 10 to the power of 16 per cubic centimeter. Explicit application: "remote magnetic control of space targets." Directly comparable to US MARAUDER and Russian Stupitskiy.
- **SIOM ball lightning soliton:** Published in *Nature Photonics* (April 2026, DOI 10.1038/s41566-026-01899-y). First experimental demonstration of ball lightning as EM soliton. SULF/Xihe 10-petawatt laser. THz emission documented. Created in argon gas (critical limitation).
- **HIT plasmoid control:** 2021–2022 publications documenting EM steering and gating of plasmoids in atmospheric conditions. Collaboration with PNP Gatchina, Russia.

- **HUST HFRC facility:** 0.8-meter radius, 4.2-meter length, 0.5 Tesla in 50 microseconds. Civilian FRC research device.
- **USTC KTX feedback control:** FPGA-based 25 kHz feedback, under 50 microseconds latency.
- **EAST tokamak record:** 1,066-second H-mode discharge, January 2025 world record.
- **HL-3 tokamak:** Ion and electron temperatures exceeding 100 million degrees Celsius, 2025.
- **PLA Daily article:** July 26, 2019 article on plasma weapons as "new concept weapons." Established as a statement of institutional interest.
- **CASC MPDT breakthrough:** 100-kilowatt magnetoplasmadynamic thruster, March 2025.
- **CASC fielded HPM systems:** High-power microwave systems fielded by CASC.
- **Military-Civil Fusion policy:** National strategy since 2017, CMC-directed civilian-military technology transfer.
- **Fusion investment:** Approximately 10 billion dollars total. EMP research budget 95 billion yuan (approximately 650 million dollars) for FY2024–2028.

Strongly Inferred

The following claims are supported by multiple converging lines of evidence but not directly confirmed by primary sources:

- **Full technology chain capability:** The existence of all plasma weapons technology chain components (Established individually), combined with the Military-Civil Fusion policy framework (Established), strongly infers the capability to integrate them into a coordinated weapons program. However, no open-source evidence confirms that such integration has occurred.
- **Russia-China technology transfer:** The HIT-PNP Gatchina collaboration (Established) strongly infers a broader pattern of Russian plasma weapons expertise flowing into the Chinese research ecosystem through institutional collaboration.

Plausible Physics

The following claims are consistent with known physics but not demonstrated at weapons scale or under operational conditions:

- **Atmospheric ball lightning soliton:** The SIOM soliton demonstrates self-confinement in argon (Established). Its survival in atmospheric air is plausible physics —

the soliton mechanism is physically sound — but has not been demonstrated. The chemical reactivity, radiative losses, electron attachment, and ionization potential differences between argon and air may prevent atmospheric survival.

- **Compact toroid weapon integration:** The integration of NUDT spheromak generation, HIT plasmoid steering, USTC feedback control, and CASC pulsed power into a fielded weapon is consistent with known physics — each component is demonstrated — but has not been demonstrated as an integrated system.

Speculation

The following claims are not supported by direct evidence and are based on extrapolation or assumption:

- **Coordinated plasma weapons program:** While the technology chain is complete (Strongly inferred) and the MCF framework provides the institutional bridge (Established), the existence of a coordinated program that actively integrates all components into a weapons system is speculative. No open-source evidence confirms such a program.
- **Timeline to operational capability:** Any estimate of when China might field an operational plasma orb weapon is speculative. The technology chain exists, but the integration timeline depends on factors that are not visible in the open-source record.

Unsupported

The following claims have no experimental or theoretical support in the open-source record:

- **Fielded operational plasma orb weapon:** No confirmed fielded operational plasma orb weapon in China. No testing against satellites, no combat use, and no space-based plasma weapons have been documented. However, the absence of a confirmed fielded weapon does not mean an absence of interest: China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern.

Overall V2 Confidence Assessment: No confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern. The NUDT spheromak program — directly referencing the US MARAUDER program — is the most direct evidence of military interest in compact toroid weapons for space warfare. The SIOM ball lightning soliton is a landmark physics result representing physics validation relevant to weapons concepts, with a critical atmospheric limitation. The HIT plasmoid control experiments demonstrate atmospheric steering capability. The full technology chain assessment is Strongly inferred — all components exist, but their integration into a coordinated weapons program is not confirmed.

Comparative Assessment

China's position in the global plasma weapons landscape can be assessed relative to the other major programs:

- **United States:** Initiated the MARAUDER program (1988–1993), the earliest confirmed compact toroid weapons experiments. The US program was terminated and its personnel dispersed, though classified programs may continue. The US maintains the deepest historical experience with compact toroid weapons.
- **Russia:** Maintains the longest and most continuous plasma weapons interest continuum of any nation (66 years). The Avramenko plasmoid weapon claims are unverified but credible-sounding. The Avangard is a hypersonic system, not a plasma weapon. The Stupitskiy space plasma gun is the most credible active Russian weapons research effort, but remains in the research phase.
- **China:** The newest entrant in the 66-year global plasma weapons interest pattern. Possesses the most complete component-level technology chain of any nation — every component exists in the open-source record, with explicit military intent (PLA "new concept weapons"). The NUDT spheromak directly references MARAUDER and is the only published, peer-reviewed spheromak program outside the US with explicit space-target applications. The SIOM soliton is the first experimental demonstration of ball lightning as an EM soliton, representing physics validation relevant to weapons concepts. However, no confirmed fielded operational weapon.

China's distinctive position is that it combines the breadth of the US technology chain (spheromak generation, plasmoid control, pulsed power) with the institutional coordination of the Russian system (state-directed, military-civil fusion), while also contributing unique

advances (the SIOM soliton, the USTC feedback control). The result is a technology chain that is complete on paper but unconfirmed in practice.

The SIOM Limitation in Context

The SIOM ball lightning soliton's atmospheric limitation deserves emphasis in the overall assessment. The soliton experiment is a landmark physics result — the first experimental demonstration of a concept that has been discussed theoretically for decades. But the argon environment is not a minor caveat; it is a fundamental limitation on the experiment's weapons relevance.

A plasma weapon that only works in argon has no military utility. The atmosphere is approximately 78 percent nitrogen and 21 percent oxygen — both chemically reactive gases that interact with plasma in ways that argon does not. The chemical reactivity, radiative losses, electron attachment, and ionization potential differences between argon and air may prevent the soliton from persisting in atmospheric conditions. Until the soliton's atmospheric survival is demonstrated, the SIOM experiment must be categorized as a physics result with Plausible physics weapons relevance — not as evidence of an atmospheric plasma weapon.

Assessment Caveat: The SIOM ball lightning soliton experiment should not be cited as evidence of an operational atmospheric plasma weapon. The experiment was conducted in argon gas, not atmospheric air. The soliton's atmospheric survival is unproven. Any assessment that claims the SIOM experiment demonstrates an atmospheric plasma weapons capability is incorrect and does not reflect the evidence in the published record.

Open Questions

Several significant questions about China's plasma weapons program remain open:

1. **Integration status:** Has the technology chain been integrated into a coordinated weapons program? The components exist (Established), but their integration is not confirmed (Strongly inferred at best, Speculative without further evidence).
2. **NUDT spheromak testing:** Has the NUDT spheromak been tested against space targets, or only in laboratory conditions? The publication documents the device and its parameters, but does not confirm testing against actual targets.
3. **Atmospheric soliton survival:** Can the SIOM ball lightning soliton survive in atmospheric air? This is the critical open question for the ball lightning weapons pathway. No experimental evidence in the open-source record addresses this question.

4. **HIT plasmoid control at weapons scale:** The HIT experiments demonstrated EM steering of plasmoids in atmosphere. Have these experiments been scaled to weapons-relevant velocities, energies, and distances?
5. **Space-based plasma weapons:** Has any Chinese program tested plasma weapons in space or against orbital targets? No open-source evidence confirms such testing.
6. **MCF transfer events:** What specific technology transfers from civilian to military programs have occurred under the Military-Civil Fusion framework? The policy exists (Established), but specific transfer events are not documented in the open-source record.

Final Assessment

China's plasma weapons program is defined by a paradox: it possesses the most complete component-level technology chain of any nation in the open-source record, with explicit military intent, yet no confirmed fielded operational weapon. Every component — spheromak generation (directly referencing MARAUDER), plasmoid steering, feedback control, high-power plasma generation, ball lightning physics (representing physics validation relevant to weapons concepts), directed energy systems — is individually Established. The Military-Civil Fusion policy provides the institutional bridge for integration. The PLA has expressed explicitly documented institutional interest in plasma weapons as "new concept weapons." The investment is massive — approximately 10 billion dollars in fusion and 650 million dollars in EMP research over five years.

But the V2 confidence framework demands rigor. The existence of components is not the existence of a system. The NUDT spheromak is a published device, not a fielded weapon. The SIOM soliton is a physics result in argon, not an atmospheric plasma weapon. The HIT plasmoid control is a laboratory demonstration, not a combat system. The PLA Daily article is a statement of explicitly documented interest, not a confirmation of capability. The full technology chain is Strongly inferred — and a fielded operational plasma orb weapon is unconfirmed. China represents the newest entrant in the 66-year global plasma weapons interest pattern, with the most complete component-level technology chain and explicit military intent.

The implication is not that China lacks plasma weapons capability — it is that the open-source record does not confirm a fielded weapon. China's program may be more advanced than the open-source evidence reveals; classified programs, by definition, are not visible in open sources. But this investigation is an OSINT analysis, and its conclusions are bounded by what the open-source record establishes. What the record establishes is a complete

component-level technology chain with explicit military intent, a military-civil fusion framework, and explicitly documented institutional interest — representing the newest entrant in the 66-year global plasma weapons interest pattern.

Final Assessment (V2 Confidence Framework): No confirmed fielded operational plasma orb weapon, but China has assembled a complete component-level technology chain with explicit military intent (PLA "new concept weapons"), representing the newest entrant in the 66-year global plasma weapons interest pattern (Strongly inferred). Every component is individually Established: the NUDT spheromak (space-target oriented, directly referencing MARAUDER), the SIOM ball lightning soliton (physics validation relevant to weapons concepts, with critical atmospheric limitation), the HIT plasmoid control (atmospheric steering), the USTC KTX feedback (25 kHz, under 50 microseconds), the EAST and HL-3 tokamak records, the CASC MPDT and HPM systems, and the Military-Civil Fusion policy framework. The PLA has expressed explicitly documented institutional interest in plasma weapons (Established as statement). No confirmed fielded operational plasma orb weapon in China. No testing against satellites, no combat use, and no space-based plasma weapons have been documented. The assessment is bounded by the open-source record: China's program may be more advanced than the evidence reveals, but this investigation's conclusions are bounded by what that evidence establishes.