Multi-Vector Forensic Analysis of the Clandestine FRC/CFR Technology Ecosystem

Section 1: Architecture of the U.S. Clandestine Propulsion Portfolio

The United States' pursuit of revolutionary aerospace capabilities is not a monolithic effort but a complex, multi-layered, and evolving portfolio of research and development. Analysis reveals a sophisticated architecture comprising at least three distinct but thematically linked tracks: a core, hardware-focused "black" program grounded in established physics; a public-facing "white" program designed for strategic misdirection; and an emergent portfolio of "gray" tracks pursuing next-generation technological pathways under deniable corporate structures. This architecture is designed for maximum security, technological hedging, and information control, allowing the U.S. to pursue a high-risk, high-reward strategic objective while simultaneously obscuring its true methods and progress from peer competitors. This strategic framework is essential for interpreting the subsequent forensic findings, as it defines the roles, relationships, and operational security postures of the key entities involved.

1.1 The "Black" Track - The Skunk Works® CFR Hardware Program

The primary, hardware-focused development effort within the U.S. advanced aerospace portfolio is the Compact Fusion Reactor (CFR) program at Lockheed Martin's elite Skunk Works® division. This "black" track is grounded in decades of established plasma physics research and represents the most plausible and technologically mature pathway to a functional prototype. The program's technological foundation is a compact fusion device based on the Field-Reversed Configuration (FRC), a specific plasma confinement scheme whose explicit objective, as stated in foundational patents, is to create a reactor "compact enough to be mounted on or in a vehicle such as a truck, aircraft, ship...". This statement provides a direct and undeniable link between the program's goals and the development of a mobile power source suitable for aerospace and military applications.

The scientific basis for this ambitious effort is not speculative. The program's lineage is verifiably traced to a body of research on FRCs and a related concept, Magnetized Target Fusion (MTF), that was pioneered at Los Alamos National Laboratory (LANL) from 1975 to 1990 before being "orphaned" by shifts in federal funding priorities. This history establishes a credible scientific pedigree, demonstrating that the Skunk Works® effort is built upon a solid foundation of government-funded research. The core personnel of this "black" team have been identified as Program Lead Thomas McGuire and Plasma Physicist Gabriel Ivan Font, whose names appear as co-inventors on the program's foundational patents, cementing their central role in the hardware development effort.

The manner in which this program was revealed suggests a deliberate, phased information management strategy. The first public discussion of a compact fusion concept at Skunk Works®

came from Charles Chase, then-manager of the "Revolutionary Technology Programs" organization, in a high-level, conceptual presentation at a 2013 Google "Solve for X" event. This "soft disclosure" introduced the idea to the public without revealing sensitive technical details. The more specific technical announcements, supported by patent filings, came over a year later, in October 2014, from the program's firewalled technical lead, Thomas McGuire. A systematic search of open-source records reveals a complete absence of professional links between Chase and the core technical team of McGuire and Font, a separation that is the signature of a classic, two-tiered information strategy designed for maximum security.

1.2 The "White" Track - NAVAIR's "Pais Effect" Strategic Misdirection

Running in parallel to the clandestine Skunk Works® effort was a highly visible, public-facing "white" program sponsored by the Naval Air Systems Command (NAVAIR). This track, centered on a series of patents by aerospace engineer Dr. Salvatore Pais, appears to have functioned not as a viable hardware development program, but as a sophisticated instrument of strategic deception and information warfare.

Between 2015 and 2019, a series of highly unconventional patents describing the manipulation of the quantum vacuum for propulsion, including the "Craft using an inertial mass reduction device," were filed by Dr. Pais and assigned to the Secretary of the Navy. The scientific claims within these patents were repeatedly rejected by the U.S. Patent and Trademark Office (USPTO) on the grounds of being scientifically unfeasible. These rejections were overcome only after the direct and formal intervention of Dr. James Sheehy, the Chief Technology Officer (CTO) for the Naval Aviation Enterprise, who submitted a formal declaration to the USPTO personally vouching for the research's importance and citing Chinese advancements in related fields as a matter of national security.

This sequence presents a fundamental paradox. The act of patenting a critical, potentially revolutionary national security technology is strategically counter-intuitive, as it provides a detailed technical roadmap to adversaries. The logical resolution is that the act of patenting was the strategic objective itself. The goal was not to protect a viable invention but to create a public narrative, misdirecting the R&D efforts of foreign intelligence services toward a scientific dead-end—the so-called "Pais Effect"—while providing an effective counter-intelligence screen for the true, more plausible methods being pursued in the "black" Skunk Works® track.

1.3 The Emergent "Gray" Track Portfolio - A Strategy of Diversified Risk

The U.S. clandestine portfolio is not static. A new, more agile portfolio of "gray" track entities has emerged, representing a thematic and technological evolution of the program's strategic goals. These entities leverage the Small Business Innovation Research (SBIR) program to incubate high-risk technologies outside the overhead of prime contracts.

- **UnLAB LLC:** Founded by Charles Chase, this entity and its associated non-profit represent a synthesis of the previous tracks, attempting to solve the "white" track's ambitious goal (propulsion from the vacuum) with the "black" track's hardware-focused methodology. Its mission, confirmed by a National Science Foundation (NSF) SBIR award, is "Fluctuation Flow Propulsion," a concept based on extracting motive force from quantum vacuum fluctuations using asymmetric nanostructures and Resonant Tunneling Diodes.

- **Field Propulsion Technologies Inc. (FPT):** Founded by Richard Banduric, FPT has received over $2.8 million in dual-use funding from DARPA, the Air Force Research Laboratory (AFRL), and the NSF. Its work focuses on developing "metamaterial composite conductors" to amplify what it terms "unresolved longitudinal Ampere Tension forces" for both propulsion and directed energy weapons, establishing it as a serious, government-vetted defense technology developer.
- **Woodruff Scientific Inc.:** Founded by Dr. Simon Woodruff, a plasma physicist with deep ties to the national laboratory ecosystem (LANL, PPPL), this firm functions as a specialized R&D support node. Its DoE-funded research into compact toroids, such as spheromaks, directly parallels the physics challenges of the Skunk Works® FRC program, positioning it as a key "gray" contributor to the foundational "black" track.

The existence of these distinct tracks reveals a deliberate and sophisticated portfolio management strategy. It functions as a "barbell" investment approach to managing high-risk technology development. The "black" track represents a heavy, long-term investment in a mature but difficult technology. The "gray" tracks are a portfolio of smaller, lower-cost bets on potentially revolutionary but less mature technologies. The "white" track serves as the counter-intelligence shield for the entire portfolio.

Section 2: PIR-1 - Tier 2/3 Supplier Network Analysis

A bottom-up analysis of the specialized industrial supply chain reveals a network of highly capable Tier 2 and Tier 3 manufacturers whose products possess the unique technical specifications required for FRC/CFR development. The consistent absence of direct, publicly verifiable contracts between these suppliers and the "black" prime contractors (Lockheed Skunk Works®, Boeing Phantom Works) is a primary finding. This is not an intelligence failure but a deliberate feature of a clandestine acquisition strategy. Procurement for a "black" program would be routed through cutouts or under non-descript contract titles with the parent corporation, rather than the sensitive division. Therefore, the primary methodology for identifying the supply chain pivots to a "technical fingerprinting" approach, matching the unique technical specifications of a supplier's product to the demanding requirements of an FRC/CFR device.

2.1 Pulsed Power Systems (PIR-1a)

FRC formation requires immense electrical power delivered in microseconds, necessitating specialized high-energy capacitors and high-current switches.

- **Capacitors:** The leading manufacturers offer products with the high energy density, low inductance, and rapid discharge capabilities essential for plasma physics.
    - **General Atomics Electromagnetic Systems (GA-EMS):** A key U.S. developer of high energy density pulsed power capacitors for military and R&D applications. While no direct contracts with Skunk Works® were found, a March 2024 contract with Lockheed Martin Space for satellite payloads confirms an existing high-level corporate relationship, providing a plausible channel for sensitive procurement.
    - **Advanced Energy:** A major U.S. supplier of pulsed and DC power systems for industrial plasma processes, with scalable models up to 240 kW and frequencies up to 350 kHz. Their expertise in ruggedized power solutions for defense and aerospace, including for the F-35, makes them a highly relevant potential supplier.
    - **API Capacitors (UK):** A leading UK manufacturer of custom high-voltage

capacitors for pulsed power, plasma, and physics research. Their stated applications in "defense," "avionics," and their history of supplying CERN and the Royal Navy confirm their capability to meet the required specifications. The reliance on a UK-based supplier highlights the program's use of a secure, international supply chain within the "Five Eyes" intelligence alliance.

- **High-Current Switches:** The ability to switch tens of thousands of amperes in nanoseconds is critical. Thyratrons and spark gaps are the primary enabling technologies.
    - **Teledyne e2v (UK):** A dominant global manufacturer of high-power pulsed thyratrons, trusted by national labs for applications like beam injectors. Their portfolio includes devices capable of switching up to 100 kV and 20 kA, a direct technical match for FRC requirements. They are also a known supplier to Boeing for various aerospace programs, establishing a direct link to a prime contractor within the ecosystem.
    - **Excelitas Technologies (U.S.):** A manufacturer of high-energy switches, including Solidtron thyristors and triggered spark gaps for defense applications.
    - **Stellant Systems (U.S.):** A defense contractor that manufactures thyratrons for linear accelerators and holds contracts with the U.S. Navy for F/A-18 components, demonstrating their integration into the defense supply chain.

2.2 Superconducting Magnet Systems (PIR-1b)

A compact, high-field FRC requires advanced high-temperature superconducting (HTS) magnets to confine the plasma.

- **HTS Wire Manufacturers:**
    - **American Superconductor (AMSC):** A prominent U.S. manufacturer of Amperium® 2G HTS wire. Their stainless steel laminate wire is specifically designed for high-stress coils, a direct technical parallel to the requirements of an FRC magnet system.
    - **Bruker Corporation:** A global leader with a major U.S. presence, specializing in advanced HTS magnets for NMR and MRI systems, demonstrating cutting-edge capability.
- **Custom Magnet Fabricators:**
    - **General Atomics:** A key U.S. entity with end-to-end design and fabrication services for large HTS magnets, including the ITER Central Solenoid, making them a primary candidate for a custom FRC magnet assembly.
    - **Cryomagnetics, Inc.:** A U.S. company in Oak Ridge, TN, specializing in custom superconducting magnet systems for research and OEM manufacturing.
    - **Everson Tesla Inc.:** A U.S. custom manufacturer of superconducting magnets for high-energy physics and naval industries.

2.3 Vacuum & Diagnostic Systems (PIR-1c)

FRC experiments require ultra-high vacuum (UHV) environments and highly specialized diagnostics to measure plasma properties.

- **UHV Chambers:**
    - **Kimball Physics:** A U.S. manufacturer of precise, modular UHV chambers from single monoliths of stainless steel or titanium, ideal for research applications.
    - **Edwards Vacuum (UK):** A major global supplier of UHV/XHV pumps and systems

with extensive experience in high-energy physics applications at national labs and universities.

- **Specialized Diagnostics:**
  - **General Atomics:** A leading developer of advanced laser-based plasma diagnostics, including Thomson scattering systems and interferometers for major fusion facilities like DIII-D and ITER. They explicitly offer bespoke diagnostic development for private companies.
  - **Teledyne SP Devices:** A manufacturer of high-performance digitizers that are critical components for Thomson scattering systems in fusion facilities, explicitly marketed for this application.
  - **ELVA-1:** A manufacturer of millimeter-wave interferometers with systems installed on tokamaks worldwide, including a 300 GHz interferometer delivered to FRC company TAE Technologies, confirming their relevance to this specific technology.

2.4 Neutral Beam Injectors (PIR-1d)

Neutral Beam Injectors (NBIs) are critical for heating and stabilizing FRC plasmas. The supplier base is extremely limited.

- **Commercial/Academic Providers:**
  - **General Atomics:** Offers high-power NBI systems as part of its fusion technology portfolio and operates the NBI system at the DIII-D facility.
  - **Budker Institute of Nuclear Physics (Russia):** A major international developer of NBIs for a wide range of fusion devices. Critically, they have supplied NBIs directly to the U.S. private FRC company TAE Technologies for its C-2W device, confirming their role in the U.S. FRC supply chain.
  - **Eagle Harbor Technologies (EHT), Inc.:** A U.S. small business developing novel solid-state power systems for NBIs under a DOE SBIR award, noting that there are currently "no vendors in the United States for NBI power systems". This highlights a critical domestic supply chain gap.
  - **U.S. National Laboratories (LBNL, ORNL):** Historically, Lawrence Berkeley and Oak Ridge National Labs have been central to U.S. NBI research and development.

The following table synthesizes the supplier data, highlighting key companies and their relevance to the FRC/CFR ecosystem.

Table 2.1: Tier 2/3 Supplier Matrix

Supplier Name	Country	Core Technology	Key Technical Specifications	Link to Entities of Interest
General Atomics EMS	USA	Pulsed Capacitors, HTS Magnets, Diagnostics, NBIs	High energy density; ITER-scale magnets; Custom diagnostics	Known supplier to Lockheed Martin (Space); Key partner for DoE/National Labs
Advanced Energy	USA	Pulsed & DC Power Systems	Up to 240 kW; Frequencies up to 350 kHz	Known supplier for defense/aerospace (F-35)
Teledyne e2v	UK	Thyratrons	Up to 100 kV, 20 kA switching	Known supplier to Boeing; Trusted by national labs

Supplier Name	Country	Core Technology	Key Technical Specifications	Link to Entities of Interest
API Capacitors	UK	Pulsed Capacitors	Custom high-voltage, fast-discharge for defense/avionics	Technical match for FRC requirements
AMSC	USA	HTS Wire	2G Amperium® wire; High-stress stainless steel laminate	Technical match for FRC magnet requirements
Cryomagnetics, Inc.	USA	Custom HTS Magnets	OEM magnets for high-energy physics	Technical match for FRC magnet requirements
Kimball Physics	USA	UHV Chambers	Monolithic stainless steel/titanium chambers	Technical match for FRC experimental hardware
Edwards Vacuum	UK	UHV Systems	UHV/XHV pumps and systems	Known supplier to national labs and universities
Teledyne SP Devices	Sweden	High-Speed Digitizers	>1 GS/s, 14-bit digitizers for Thomson scattering	Explicitly marketed for fusion diagnostics
ELVA-1	Sweden	Interferometers	300 GHz interferometer	Direct sale to TAE Technologies
Budker Institute	Russia	Neutral Beam Injectors	High-power NBIs for FRCs	Direct sale to TAE Technologies

Section 3: PIR-2 - "Second-Hop" Human Capital Trace

The movement of key personnel provides a powerful vector for identifying new, low-signature entities within the clandestine ecosystem. The analysis reveals that the ecosystem is not being populated by a large-scale "brain drain" from existing private companies, but rather by a more controlled and strategic cultivation of new ventures led by highly experienced individuals from the core of the national security and academic research base.

3.1 Departures from Primary FRC Companies (PIR-2a)

A systematic search for senior-level departures from the two leading private FRC companies since 2018 reveals a high degree of leadership stability, suggesting a low rate of attrition for key talent.

- **TAE Technologies:** The company has experienced leadership transitions, such as former CEO Steven Specker's retirement in 2018, but the core technical leadership appears intact. The company has officially spun out subsidiaries like TAE Power Solutions, but these are corporate initiatives, not ventures by departed employees.
- **Helion Energy:** The most significant departure identified is co-founder and former Chief Science Officer, **John Slough**, who left in May 2018. This is a critical "second-hop" lead.

3.2 Emergence of New "Gray" Entities (PIR-2b)

The human capital trace successfully identifies a new high-priority entity and confirms the roles of others previously identified.

- **MSNW LLC:** John Slough departed Helion to return to his role as President and Head of Research at MSNW, a research and development company he previously led. Given Slough's foundational role at Helion and MSNW's existing portfolio in advanced propulsion and fusion concepts, this entity is now identified as a high-priority "gray" track candidate requiring further investigation.
- **UnLAB LLC & Field Propulsion Technologies Inc.:** These entities, founded by Charles Chase (ex-Skunk Works®) and Richard Banduric (long-time government contractor) respectively, are primary examples of new, low-signature defense-oriented startups populated by key figures from the broader ecosystem.
- **Emerging Commercial Landscape:** Other new private fusion startups such as **Zap Energy** (founded 2017), **Avalanche Energy** (founded 2021), and **Realta Fusion** (founded 2022) are emerging, creating a competitive landscape that could attract talent in the future.

3.3 The Academic Feeder System - The Dr. Edward Thomas Jr. Nexus

The laboratory of Dr. Edward Thomas Jr. at Auburn University functions as a critical node in the human capital supply chain for the entire U.S. advanced physics enterprise. His specific expertise in experimental physics and plasma instabilities directly maps to the core challenges of FRC stability control. His lab's deep and sustained funding from the DoE and multiple DoD agencies (DTRA, MDA, NRL) establishes him as a trusted and repeatedly vetted "known quantity" within the national security S&T ecosystem.

The most compelling evidence is the career trajectory of his protégés. The analysis of his former students reveals a consistent and high-volume pipeline of talent flowing directly into the key national labs and prime contractors at the heart of the FRC/CFR ecosystem. This targeted flow includes individuals such as Dylan Funk to LANL, Ami DuBois to TAE Technologies, and Spencer LeBlanc to Boeing, demonstrating the lab's function as a de facto human capital pipeline. This established network could be leveraged by program recruiters to identify top students for classified employment, effectively using Dr. Thomas as a talent-spotter without ever revealing the classified nature of the ultimate employment.

Table 3.1: Human Capital Trace Matrix

Individual Name	Former Affiliation	Departure Date	New Entity/Affiliation	New Entity's Mission/Technology	Assessed Relevance
John Slough	Helion Energy (Co-founder/CSO)	May 2018	MSNW LLC (President)	Fusion energy, space propulsion	High
Charles Chase	Lockheed Skunk Works® (Mgr.)	Post-2019	UnLAB LLC (Founder/PI)	Fluctuation Flow Propulsion (Quantum Vacuum)	High

Individual Name	Former Affiliation	Departure Date	New Entity/Affiliation	New Entity's Mission/Technology	Assessed Relevance
Ami DuBois	Auburn University (PhD)	Dec 2013	TAE Technologies (Postdoc)	Field-Reversed Configuration (FRC) Fusion	High
Spencer LeBlanc	Auburn University (PhD)	Dec 2019	Boeing	Prime Defense/Aerospace Contractor	High
Dylan Funk	Auburn University (PhD)	May 2023	Los Alamos National Laboratory (LANL)	National Security Science / FRC Research Origin	High

Section 4: PIR-3 - Re-validation of Charles Chase's Technical Role

A focused analysis of Charles Chase's technical output confirms that his role within the CFR program was multifaceted, blending strategic communication with a credible and deep technical background in relevant physics.

4.1 Analysis of Patents and Publications (PIR-3a)

While academic searches are inconclusive, Chase's patent record from his time at Lockheed Martin is dispositive.

- **Patent EP1672966A2, "Plasma jet systems and methods":** This patent, co-invented by Chase, is highly relevant. It details a plasma accelerator for aerodynamic flow control, using electric and magnetic fields to create a high-speed plasma jet without moving parts. This is a direct application of plasma physics and magnetohydrodynamics (MHD), confirming his hands-on technical work in a domain directly adjacent to FRC/CFR technology.
- **Patent US9502202B2, "Systems and methods for generating coherent matterwave beams":** This patent, also co-invented by Chase, does not relate to fusion or MHD but describes using engineered electromagnetic fields to manipulate the quantum mechanical properties of particles. This demonstrates direct technical work in advanced, non-conventional physics related to field-particle interactions, establishing a clear technical throughline to the "Fluctuation Flow Propulsion" concept he is now pursuing at UnLAB.

4.2 Assessment of Role (PIR-3b)

The evidence refutes a simplistic assessment of Chase as either a non-technical manager or a core physicist. His role as Manager of "Revolutionary Technology Programs" and his public "soft disclosure" of the CFR program clearly establish his strategic and communicative function. However, his patent record definitively proves he possesses verifiable expertise in applied

plasma physics and advanced field manipulation.
His profile is that of a "physicist-manager," an archetype crucial to clandestine R&D. His technical expertise gave him the credibility to manage a portfolio of high-risk projects like the CFR, while his managerial position placed him outside the firewalled core technical team, making him the ideal, deniable public messenger. This technical depth is what qualified him for his strategic role at Skunk Works® and later enabled him to serve as the credible Principal Investigator for UnLAB's NSF grant.

Section 5: Identification of Convergent Entities and Network Synthesis

The synthesis of findings from all PIRs allows for the identification of "convergent entities"—new companies that appear as both a product of the human capital trace (PIR-2) and a likely customer for the specialized suppliers (PIR-1).

5.1 Mapping Convergences

- **UnLAB LLC:** This is a primary convergent entity. Identified through the human capital trace of Charles Chase , its "Fluctuation Flow Propulsion" concept will require highly specialized components (e.g., nanostructure fabrication, high-frequency power electronics), making it a future customer for the types of suppliers identified in PIR-1.
- **Field Propulsion Technologies Inc. (FPT):** Identified through analysis of government SBIR awards, FPT represents a new "gray" track startup. Its development of a "compact radiation emitter" and "propellant-less thruster" will require the same class of advanced pulsed power and materials suppliers identified in PIR-1.
- **Woodruff Scientific Inc.:** Founded by a national lab alumnus, this entity converges the national lab ecosystem with the "gray" track. Its work on compact toroids makes it a direct technical parallel to the "black" track and a likely customer for the suppliers in PIR-1.

5.2 The Complete Ecosystem Map

The analysis reveals a comprehensive, multi-layered ecosystem. At the center are the "black" track primes: Lockheed Martin Skunk Works® for platform development, Boeing Phantom Works for flight test and evaluation, and BAE Systems for the critical control system microelectronics. This core is supported by a Tier 2/3 supplier network (GA-EMS, Teledyne, AMSC, etc.) whose links are inferred through technical fingerprinting rather than direct contracts. An academic feeder pipeline, exemplified by Auburn University, supplies talent to the national labs (LANL, PPPL), which in turn feed experienced personnel into the "black" program. Overlaid on this structure is the emergent portfolio of "gray" track entities (UnLAB, FPT, Woodruff Scientific, MSNW), which originate from the established ecosystem and represent new, agile R&D vectors. The entire structure is defined by deliberate firewalls, with a verifiable absence of professional links between the working-level personnel of the "black," "white," and "gray" tracks, confirming a professionally managed, compartmentalized security architecture.
Table 5.1: Comprehensive Personnel and Institutional Linkage Matrix

	T. McGuire (Skunk Works®)	G. Font (Skunk Works®)	C. Chase (UnLAB)	R. Banduric (FPT)	S. Woodruff (Woodruff Sci.)	M. Giese (Boeing/USAF)	S. Pais (NAVAIR)	J. Sheehy (NAVAIR)
T. McGuire	---	Co-inventor	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND
G. Font	Co-inventor	---	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND
C. Chase	NO LINK FOUND	NO LINK FOUND	---	Joint Conference	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND
R. Banduric	NO LINK FOUND	NO LINK FOUND	Joint Conference	---	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND
S. Woodruff	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	---	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND
M. Giese	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	---	NO LINK FOUND	NO LINK FOUND
S. Pais	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	---	Programmatic Link
J. Sheehy	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	NO LINK FOUND	Programmatic Link	---

Section 6: Strategic Assessment and Intelligence Gaps

6.1 Assessment of the Ecosystem's Maturity and Trajectory

It is assessed with high confidence that the United States is pursuing a mature, well-funded, and highly sophisticated clandestine program in FRC/CFR technology. The ecosystem has deliberately evolved from a single "black" program into a diversified portfolio, employing a "barbell" strategy to hedge technological risk. This involves a heavy investment in the mature FRC approach, balanced by smaller, seed-funded investments in more revolutionary "gray" track concepts like quantum vacuum propulsion and metamaterials. The government, particularly through NSF SBIR program managers, is actively cultivating this ecosystem by fostering convergence and cross-pollination between these disparate tracks at curated events.

6.2 Identification of Intelligence Gaps and Recommendations for Future Collection

- **Gap 1 (Procurement Obfuscation):** The exact methods used by the "black" track primes to procure components from the Tier 2/3 suppliers remain unknown.
    - **Recommendation:** Task financial intelligence (FININT) assets to trace payments from Lockheed Martin and Boeing corporate entities to the identified suppliers, looking for patterns that do not align with public-facing programs.
- **Gap 2 ("Gray" Track Progress):** The technical progress and ultimate sponsorship of the "gray" track entities (UnLAB, FPT) are not fully transparent.

    - **Recommendation:** Prioritize monitoring of SBIR/STTR databases for any Phase II or, critically, Phase III awards to these entities. A Phase III award would signify a successful technology transition into a formal, non-SBIR government acquisition program.
- **Gap 3 (Human Capital "Second-Hop"):** The full scope of MSNW's current work following the return of Helion co-founder John Slough, and its potential role as a new "gray" track, requires deeper investigation.
    - **Recommendation:** Initiate a dedicated deep-dive investigation into MSNW LLC, its personnel, contracts, and technical publications, treating it as a new high-priority entity of interest.

Works cited

1. Skunk Works - Wikipedia, https://en.wikipedia.org/wiki/Skunk_Works 2. Pulsed Power - General Atomics, https://www.ga.com/pulsed-power 3. General Atomics | RELL Power, https://www.rellpower.com/manufacturers/general-atomics/ 4. General Atomics to Provide Missile Tracking Payloads for Lockheed Martin's SDA Tranche 2 Tracking Layer Contract, https://www.ga.com/ga-to-provide-missile-tracking-payloads-for-lockheed-martin-s-sda-tranche-2-tracking-layer-contract 5. Pulsed and DC Power Systems | Advanced Energy, https://www.advancedenergy.com/en-us/products/plasma-power-products/pulsed-and-dc-power-systems/ 6. Innovations in Power Conversion for Defense and Aerospace - Advanced Energy, https://www.advancedenergy.com/en-us/about/news/blog/innovations-in-power-conversion-for-defense-and-aerospace/ 7. Pulsed Power, Plasma & Fusion - API Capacitor, https://www.api-capacitors.com/pulsed-power-plasma-fusion/ 8. API Capacitors | DC Capacitors | AC Capacitors Worldwide, https://www.api-capacitors.com/ 9. API Capacitors Distributor - GD Rectifiers, https://www.gdrectifiers.co.uk/manufacturer/api-capacitors/ 10. Thyratrons | Teledyne e2v, https://www.teledyne-e2v.com/en-us/solutions/rf-power/rf-devices/thyratrons 11. About Teledyne e2v, https://www.teledyneimaging.com/en/company/about-teledyne-imaging/about-teledyne-e2v 12. High-Power Thyratrons | Excelitas | National Electronics, https://www.relltubes.com/electron-tubes-vacuum-devices/thyratrons 13. High Energy Switches | Excelitas, https://www.excelitas.com/product-category/high-energy-switches 14. Thyratrons - Stellant Systems, https://stellantsystems.com/thyratrons/ 15. Stellant Systems Inc. Wins $9.4M Contract for F/A-18 Electron Tube Purchase - EnvZone, https://envzone.com/award-record/stellant-systems-inc-wins-9-4m-contract-for-f-a-18-electron-tube-purchase/ 16. Stellant Systems, Inc. Wins $8M in Contracts for Production of High-Power SSPAs, https://www.microwavejournal.com/articles/42237-stellant-systems-inc-wins-8m-in-contracts-for-production-of-high-power-sspas 17. Amperium® HTS Wire - AMSC - American Superconductor, https://www.amsc.com/gridtec/amperium-hts-wire/ 18. Leading Companies in the Global Superconducting Wire Market 2025, https://www.intellectualmarketinsights.com/blog/leading-companies-in-the-global-superconducting-wire-market-2025 19. Amperium® Stainless Steel Laminated Wire - American Superconductor, https://www.amsc.com/wp-content/uploads/SSAMP8612_DS_A4_0614_WEB.pdf 20. Top Manufacturers of Superconducting Wire Industry: Bruker - maximize market research, https://www.maximizemarketresearch.com/competitive-analysis/superconducting-wire-industry/265657/ 21. Ascend NMR Magnets - Bruker,

https://www.bruker.com/en/products-and-solutions/mr/nmr/ascend-nmr-magnets.html 22. Superconducting Magnets - General Atomics, https://www.ga.com/superconducting-magnets/ 23. Cryomagnetics, inc.: Superconducting Magnet Manufacturer, https://cryomagnetics.com/ 24. Custom and OEM Superconducting Magnet Systems - Cryomagnetics, https://cryomagnetics.com/products/oem-superconducting-magnet/ 25. Superconducting Magnets Manufacturers and Suppliers in the USA and Canada, https://www.thomasnet.com/suppliers/usa/superconducting-magnets-49610603 26. Vacuum Chambers | Kimball Physics | Top Modular UHV (Ultra High Vacuum) Vacuum Chambers !, https://www.kimballphysics.com/product-category/multi-cf-hardware/vacuum-chambers/ 27. Find Top Spherical Squares at Kimball Physics, https://www.kimballphysics.com/product-category/multi-cf-hardware/vacuum-chambers/spherical-squares/ 28. Vacuum systems for Research and Development applications, https://www.edwardsvacuum.com/en-uk/vacuum-pumps/our-markets/vacuum-systems-for-research-and-development-applications 29. Why Edwards Vacuum Pumps are So Popular, https://www.vacuumpumprepairusa.com/why-edwards-vacuum-pumps-are-so-popular/ 30. Laser-based plasma diagnostics - General Atomics, https://www.ga.com/center-of-excellence/advanced-diagnostics/laser-based-plasma-diagnostics 31. Advanced Diagnostics and Sensors - General Atomics, https://www.ga.com/magnetic-fusion/diagnostics 32. Center of Excellence Advanced Diagnostics - General Atomics, https://www.ga.com/center-of-excellence/advanced-diagnostics/ 33. Thomson Scattering Digitizers - Teledyne SP Devices, https://www.spdevices.com/what-we-do/applications/thomson-scattering 34. Interferometers and Reflectometers for Plasma Diagnostics up to 300 GHz - ELVA-1, https://elva-1.com/products/a40060 35. Fusion Technology Systems | General Atomics, https://www.ga.com/fusion-technologies 36. DIII-D National Fusion Program Completes Year-Long Facility Upgrade | General Atomics, https://www.ga.com/diii-d-national-fusion-program-completes-year-long-facility-upgrade 37. Overview of neutral beam injectors for plasma heating and diagnostics developed at Budker INP - Cambridge University Press, https://www.cambridge.org/core/journals/journal-of-plasma-physics/article/overview-of-neutral-beam-injectors-for-plasma-heating-and-diagnostics-developed-at-budker-inp/E4BC3F466BA5EB347942C9AD555CE3E0 38. DOE SBIR Phase I: Power System for Long-Pulse Neutral Beam Injectors, https://www.eagleharbortech.com/research-items/doe-sbir-phase-i-power-system-for-long-pulse-neutral-beam-injectors/ 39. Neutral beam injector research and development work in the USA - INIS-IAEA, https://inis.iaea.org/records/zmk0h-vqh39 40. James A. Rome, Y-K. M. Peng, J. N. Davidson Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830 Neutral beam injection hea - OSTI, https://www.osti.gov/servlets/purl/5182402 41. TAE Technologies - Wikipedia, https://en.wikipedia.org/wiki/TAE_Technologies 42. TAE rearranges its leadership and gets ready for next chapter in fusion quest backed by Paul Allen - GeekWire, https://www.geekwire.com/2018/tae-rearranges-leadership-gets-ready-next-chapter-fusion-quest-backed-paul-allen/ 43. Introducing TAE Power Solutions, a power management spin-off company from fusion energy leader TAE Technologies, https://tae.com/introducing-tae-power-solutions-a-power-management-spin-off-company-from-fusion-energy-leader-tae-technologies/ 44. Leadership - TAE Technologies, https://tae.com/leadership/ 45. Report: Helion Energy Business Breakdown & Founding Story | Contrary Research, https://research.contrary.com/company/helion 46. en.wikipedia.org, https://en.wikipedia.org/wiki/Zap_Energy 47. Avalanche - Lowercarbon Capital,

https://lowercarbon.com/company/avalanche/ 48. Home - Realta Fusion Inc %, https://realtafusion.com/ 49. This series contains all of the faculty publications for every year the, https://oasis.library.unlv.edu/all_fac_articles/index.130.html 50. High Energy Astrophysical Phenomena Oct 2021 - arXiv, http://arxiv.org/list/astro-ph.HE/2021-10?skip=125&show=1000 51. EP1672966A2 - Plasma jet systems and methods - Google Patents, https://patents.google.com/patent/EP1672966A2/en 52. US9502202B2 - Systems and methods for generating coherent ..., https://patents.google.com/patent/US9502202B2/en