# Network Link Analysis: The LANL-AFRL MTF Collaboration

## 1. Analysis of Programmatic History & Objectives

The scientific foundation for advanced compact fusion concepts within the U.S. defense and aerospace sector is rooted in a multi-year, multi-institutional collaboration between Los Alamos National Laboratory (LANL) and the Air Force Research Laboratory (AFRL). This joint effort, centered on the concept of Magnetized Target Fusion (MTF), established a clear, evolutionary pathway from a foundational plasma injector to a fully integrated liner compression experiment. This progression reveals a deliberate, methodical strategy to mature a high-risk, high-reward technology within the U.S. national laboratory system, culminating in a body of experimental work that would directly inform subsequent clandestine programs.

### 1.1. Technical History Reconstruction: An Evolutionary Pathway to Liner Compression

The collaboration's research arc is defined by three distinct but inextricably linked experimental devices: the Field Reversed Experiment-Liner (FRX-L), the Magnetized Shock Experiment (MSX), and the Field-Reversed Configuration Heating Experiment (FRCHX). A chronological reconstruction of these programs demonstrates a direct lineage in terms of hardware, design philosophy, and scientific objectives, representing a coherent, step-wise technology maturation pipeline.

#### 1.1.1. The Foundation: The FRX-L Experiment (c. 2001-2003)

The genesis of the modern high-density Field-Reversed Configuration (FRC) research track was the FRX-L experiment at Los Alamos National Laboratory. Active in the 2001-2003 timeframe, FRX-L served as the foundational plasma injector for the broader Magnetized Target Fusion (MTF) program. The experiment's primary technical objective was to produce a stable, high-density, and translatable FRC plasma with parameters suitable for subsequent adiabatic compression by an imploding solid metal liner. The specific design goals were to achieve a plasma with a density (n) of approximately $10^{17}$ cm$^{-3}$, a total temperature ($T_e + T_i$) of approximately 300 eV, and a trapped-flux lifetime of 10-20 μs. These parameters were not arbitrary; they were identified as the essential starting conditions for a viable MTF target.
The FRX-L hardware was centered on a theta-pinch coil driven by a formidable pulsed-power system composed of four high-voltage capacitor banks capable of storing up to 1 MJ of energy. During its operational period, the experiment underwent continuous upgrades, including the planned installation of cusp/mirror coils in late 2002 to improve the reproducibility of plasma formation by seeding magnetic reconnection in a consistent location. By 2003, the experiment had successfully demonstrated the formation of FRCs with densities of 2-4 x $10^{16}$ cm$^{-3}$ and lifetimes of 10-15 μs, achieving performance within a factor of 2 to 3 of the ultimate design goals. This success was a critical proof-of-concept, validating the fundamental approach and providing the direct design basis and operational experience for the more ambitious, fully

integrated FRCHX experiment that would follow.

### 1.1.2. The Testbed: The Magnetized Shock Experiment (MSX)

Following the initial phase of FRX-L operations, the Magnetized Shock Experiment (MSX) was established at LANL as its direct hardware and conceptual successor. Active circa 2013-2015, MSX was explicitly constructed using "much of the equipment from the discontinued Field-Reversed Experiment with Liner (FRX-L) program". This direct hardware inheritance demonstrates a clear pattern of resource and knowledge reuse within the LANL plasma physics group, ensuring continuity of expertise and maximizing the return on investment in specialized pulsed-power hardware.

MSX served a critical dual purpose. Its primary stated scientific objective was to investigate the fundamental physics of magnetized, collisionless shocks in a laboratory setting, a topic with broad applications in astrophysics and plasma physics. However, its essential programmatic role was to function as a flexible and cost-effective testbed for developing and de-risking novel technologies and techniques that were deemed critical for the success of the main-line FRCHX experiment. The fact that MSX and FRCHX utilized "nearly identical conical θ-pinch hardware" is a dispositive piece of evidence for this direct programmatic link, positioning MSX as the essential innovation hub for the broader MTF collaboration.

### 1.1.3. The Integrated System: The FRCHX Experiment (c. 2007-2013)

The Field-Reversed Configuration Heating Experiment (FRCHX) represented the operational culmination of the multi-year LANL-AFRL collaboration. The experiment was physically located at AFRL's Shiva Star facility in Albuquerque, New Mexico, a strategic decision made to leverage the unique capabilities of Shiva Star's powerful, multi-megajoule capacitor bank as the liner-driver.

The explicit technical objective of FRCHX was to conduct the first-ever integrated, end-to-end demonstration of the MTF concept. This involved a complex, precisely timed sequence of events: forming a high-density FRC based on the proven FRX-L design, translating it out of the formation region and into a capture zone, and then compressively heating it to fusion-relevant conditions with a magnetically-driven, imploding solid aluminum liner. A critical prerequisite for success was achieving an FRC trapped-flux lifetime of approximately 20 μs, a duration necessary to match the liner's implosion timescale. This lifetime requirement proved to be the program's most significant scientific and engineering challenge, becoming the central focus of its later experimental campaigns.

The FRCHX program was a multi-year effort. Design and assembly began circa 2007-2008, with initial integrated liner implosion tests planned for early 2009. The first definitive integrated test was successfully executed on April 16, 2010. Subsequent experimental campaigns, focused almost exclusively on diagnosing and extending the FRC lifetime, continued through at least July 2013, as documented in a key publication by Glen Wurden reporting a significant breakthrough in this area.

## 1.2. Personnel Dossier: The LANL-AFRL Human Capital Network

The success of the MTF collaboration was predicated on a cohesive, multi-disciplinary team of physicists, engineers, and technicians from LANL, AFRL, and external partners. This network formed the intellectual and operational core of the program, with LANL's P-24 Thermonuclear

Plasma Physics group providing the FRC expertise and AFRL providing the world-class capability in pulsed-power and liner implosions.

### LANL Personnel

- **Glen A. Wurden:** A central scientific figure whose involvement spanned all three experiments. Wurden was a key member of the foundational FRX-L team, a senior researcher in LANL's P-24 group, and the lead author on the critical 2013 paper detailing the successful extension of FRC lifetimes on FRCHX. His work directly addressed the program's primary technical obstacle, making his contributions indispensable to its progress.
- **Thomas P. Intrator (deceased June 3, 2014):** A key leader and mentor within the LANL MTF effort, remembered for his creativity and his dedication to training the next generation of plasma physicists. He was a primary author and investigator on seminal papers for FRX-L, MSX, and FRCHX. His death in mid-2014 occurred near the conclusion of the program's public research phase and marked the loss of a significant intellectual driver for the team.
- **Toru E. Weber:** The lead author on the seminal 2015 MSX paper that detailed the plasma gun-assisted formation breakthrough. This identifies him as the central figure in the development and characterization of this key enabling technology.
- **Other Key LANL Staff:** The foundational FRX-L experimental team included a deep roster of experts such as **J.M. Taccetti**, **M.G. Tuszewski**, **Z. Wang**, and **S.C. Hsu**, who were integral to establishing the initial FRC performance baseline.

### AFRL Personnel

- **John H. Degnan:** A senior AFRL researcher and the primary institutional collaborator from the Air Force side. His name is a consistent presence on numerous FRCHX publications. Degnan's extensive prior work at AFRL on solid liner implosions using the Shiva Star facility provided the foundational pulsed-power capability that made the integrated FRCHX experiment possible.
- **Chris Grabowski:** A key AFRL collaborator on FRCHX, co-authoring papers on a wide range of topics from the engineering of low-inductance crowbar switches to the critical FRC lifetime extension efforts.
- **Other Key AFRL Staff: Matthew T. Domonkos** and **Edward L. Ruden** are consistently listed as core AFRL contributors to the FRCHX experiment, particularly in publications detailing integrated liner implosion tests and FRC lifetime studies.

### External Collaborators

The program also effectively leveraged a network of external expertise. This included modeling and simulation support from specialized contractors such as **NumerEx LLC** and diagnostic and experimental support from academic partners at the **University of New Mexico** and the **University of Nevada, Reno**.

The programmatic structure and consistent personnel roster across these three experiments indicate a classic, well-managed national laboratory approach to solving a complex physics problem incrementally. First, the program proved the viability of the plasma source (FRX-L). Second, it developed and de-risked critical enabling technologies on a flexible, dedicated testbed (MSX). Third, it integrated all components for the final system-level demonstration (FRCHX). This methodical approach is the hallmark of a program intended to mature a technology to the point where its feasibility can be definitively assessed for transition to an applied, operational program.

| Personnel Name | Primary Affiliation | Experiment(s) Involved | Key Contributions |
|---|---|---|---|
| **Glen A. Wurden** | LANL | FRX-L, MSX, FRCHX | Lead researcher on FRC lifetime extension; plasma diagnostics; core scientific contributor across all program phases. |
| **Thomas P. Intrator** | LANL | FRX-L, MSX, FRCHX | Leader and mentor for the MTF effort; PI on numerous key experiments and publications. |
| **Toru E. Weber** | LANL | MSX | Lead researcher for the development and validation of plasma gun-assisted FRC formation. |
| **John H. Degnan** | AFRL | FRCHX | Lead AFRL collaborator; expert in solid liner implosions and Shiva Star operations. |
| **Chris Grabowski** | AFRL | FRCHX | Key AFRL collaborator; contributions to pulsed-power hardware (crowbar switches) and FRC lifetime studies. |
| **M. T. Domonkos** | AFRL | FRCHX | Core member of the AFRL team for integrated liner implosion tests. |
| **Edward L. Ruden** | AFRL | FRCHX | Core member of the AFRL team for integrated liner implosion tests. |
| **J. M. Taccetti** | LANL | FRX-L | Key member of the foundational FRX-L experimental team; lead author on hardware papers. |

| Date/Timeframe | Event/Milestone | Significance | Source(s) |
|---|---|---|---|
| c. 2001-2003 | FRX-L operations at | Established baseline | |

| Date/Timeframe | Event/Milestone | Significance | Source(s) |
|---|---|---|---|
| | LANL. | high-density FRC parameters, proving the viability of the plasma source. | |
| c. 2007 | FRCHX design and assembly begins at AFRL. | Marked the formal start of the integrated MTF demonstration phase, leveraging AFRL's Shiva Star. | |
| 2008 | FRX-L upgraded with conical coils. | Provided direct experimental data on FRC translation dynamics to inform the FRCHX design. | |
| Apr 16, 2010 | First integrated FRCHX liner compression test. | First-ever solid liner compression of an FRC plasma; an engineering success but revealed plasma lifetime issues. | |
| Jul 2013 | Wurden et al. report significant FRC lifetime extension on FRCHX. | Breakthrough in the program's primary technical challenge, achieving lifetimes of 14-16 μs. | |
| Jun 3, 2014 | Death of key LANL researcher Thomas P. Intrator. | Loss of a major intellectual and programmatic leader near the end of the program's public phase. | |
| Apr 29, 2015 | Publication of MSX plasma gun results. | Public documentation of the ~350% increase in trapped flux, a key enabling technology for FRCHX. | |

# 2. Analysis of Technical Integration & Related Programs

A deep analysis of the MTF program's specific technical innovations, placed in the context of the wider U.S. national security research landscape, reveals a sophisticated, portfolio-based approach to high-risk fusion research. The development of plasma gun-assisted formation on MSX was a direct, targeted response to a critical roadblock in FRCHX, while the concurrent development of the MagLIF concept at Sandia National Laboratories illustrates a broader national strategy of pursuing parallel, complementary paths to achieve Magneto-Inertial Fusion.

## 2.1. Technology Application Trace: Plasma Gun-Assisted Formation

A key technological breakthrough that was central to the program's strategy is detailed in a 2015 paper by Weber, Intrator, and Smith. This work directly addressed the primary obstacle hindering progress on the FRCHX experiment: inefficient FRC formation leading to short plasma lifetimes.

The traditional method of FRC formation, known as a "ringing θ-pinch," was particularly problematic at the high magnetic fields and densities required for MTF. This technique relied on inducing an azimuthal electric field to ionize the gas fill, a process that is suppressed by strong axial magnetic fields. Consequently, ionization typically occurred only when the confining magnetic field passed through zero, resulting in poor "trapped flux"—the key parameter for FRC stability and lifetime—and risked ablating impurities from the quartz vacuum vessel wall.

The solution developed and validated on the MSX testbed was an annular array of 12 coaxial plasma guns. These guns injected a "seed plasma" into the formation region prior to the main discharge. This seed plasma was sufficient to catalyze a Townsend ionization cascade in the bulk gas fill, even in the presence of a strong axial magnetic field. This innovation effectively decoupled the ionization process from the main field application, allowing for FRC formation under optimal conditions.

The performance improvement was dramatic and unambiguous. The plasma gun-assisted technique was shown to "significantly improve FRC formation," resulting in a landmark **~350% increase in trapped flux** at typical operating conditions. This was not an incremental improvement; it fundamentally changed the physics of flux loss during formation from a rapid, Alfvenic "convective process" to a "much slower resistive diffusion process". This directly translated to the formation of hotter, more stable FRCs with significantly longer lifetimes. The 2015 paper explicitly states that this investigation on MSX was conducted "with the intention of subsequent fielding on the Field-Reversed Configuration Heating Experiment (FRCHX)". The vastly improved FRC parameters were expected to "greatly improve prospects for heating to thermonuclear conditions during liner compression in FRCHX," representing the program's primary proposed solution to the core lifetime problem that had stalled progress in the integrated experiment.

## 2.2. Cross-Program Analysis: The Sandia MagLIF Context

The LANL-AFRL MTF program did not exist in a strategic vacuum. Its timeline and technical objectives must be understood in the context of concurrent research on liner implosions at Sandia National Laboratories (SNL), which reveals a broader national strategy for exploring MIF.

The FRCHX experiments (c. 2007-2013) were conducted in the same timeframe as the conception (2009-2010) and initial experiments (late 2013) of the Magnetized Liner Inertial Fusion (MagLIF) concept on the Z-machine at Sandia.

Both FRCHX and MagLIF are MIF concepts that rely on the Z-pinch implosion of a cylindrical metal liner to compress a pre-magnetized plasma target. While the plasma targets differ significantly—FRCHX used a self-contained, high-beta FRC, whereas MagLIF uses a laser-preheated, axially magnetized gas—the fundamental challenges of liner implosion physics are common to both approaches. Both programs had to contend with managing the destructive Magneto-Rayleigh-Taylor (MRT) instability, which threatens to break up the liner during implosion and compromise confinement.

While no documents show a direct, formal collaboration on the FRCHX and MagLIF projects themselves, there is extensive evidence of a deep, ongoing institutional partnership between LANL and Sandia on other Z-machine experiments, particularly for the stockpile stewardship mission. LANL personnel have been major users of the Z-machine for over 15 years, conducting experiments on plutonium and other materials under extreme conditions. This established relationship provided a formal, high-level channel and a culture of collaboration that makes informal knowledge sharing and cross-pollination of ideas on liner physics highly probable. The transfer of knowledge was likely facilitated by physicists and computational scientists from both labs using similar simulation codes (e.g., MACH2, LASNEX, HYDRA), attending the same specialized conferences (e.g., IEEE Pulsed Power Conference, APS-DPP), and reviewing each other's publications, creating a shared pool of expertise on pulsed-power-driven liner implosion physics.

The parallel development of FRCHX and MagLIF was not a duplication of effort but rather a deliberate portfolio strategy by the DOE/NNSA to explore two distinct, high-risk pathways to MIF, thereby hedging against technical uncertainty. MIF was identified as a promising but scientifically unproven fusion concept, and two primary technical risks existed: creating a suitable magnetized plasma target and efficiently imploding a liner onto it. The LANL/AFRL FRCHX program leveraged LANL's world-leading, multi-decade expertise in FRCs, focusing on a complex but potentially superior high-beta plasma target, making it a "target-centric" approach. Conversely, Sandia's MagLIF program leveraged the world's most powerful pulsed-power driver (the Z-machine) with a conceptually simpler, lower-risk plasma target (pre-magnetized gas), making it a "driver-centric" approach. This represents a classic risk-mitigation strategy in high-stakes R&D, allowing the national lab complex to explore the MIF parameter space from two different directions and increasing the overall probability of success for the national program.

| Technical Feature | FRCHX (LANL/AFRL) | MagLIF (Sandia) |
|---|---|---|
| **Primary Institution(s)** | Los Alamos National Laboratory, Air Force Research Laboratory | Sandia National Laboratories |
| **Pulsed-Power Driver** | Shiva Star (~5 MJ) | Z-machine (~22 MJ) |
| **Liner Material** | Aluminum | Beryllium |
| **Plasma Target** | Field-Reversed Configuration (FRC) | Deuterium gas |
| **Target Formation Method** | Reversed-field theta pinch | Laser pre-heating, axial magnetic field coils |
| **Key Instability Challenge** | FRC rotational/tilt modes; Liner MRT instability | Liner MRT instability |
| **Approx. Timeline of Key Experiments** | 2007 - 2013 | 2013 - Present |

# 3. Final Assessment

The synthesis of the programmatic, personnel, and technical analyses provides a coherent, multi-layered intelligence picture of the LANL-AFRL MTF collaboration. This body of work represents the direct scientific and engineering precursor to the Skunk Works® CFR program, successfully maturing the core FRC technology to a critical inflection point before the effort was ultimately superseded.

## 3.1. Role as Scientific Precursor to Skunk Works® CFR

The LANL-AFRL MTF collaboration provided the essential scientific proof-of-concept, experimental data, and human-capital foundation for the Skunk Works® CFR program. The technological basis of the Skunk Works® reactor is explicitly a Field-Reversed Configuration. The MTF program, culminating in the FRCHX experiment, represents the most advanced and relevant high-density FRC research conducted within the U.S. national laboratory system in the decade immediately preceding the CFR's public announcement in 2014.

The collaboration systematically tackled the fundamental challenges in high-density FRC formation, stability, translation, and lifetime. It successfully matured the technology from a laboratory concept (FRX-L) to a system ready for an integrated compression test (FRCHX), effectively "de-risking" the core plasma physics for a follow-on applied program. The established transfer of key LANL plasma physicists, such as Gabriel Ivan Font, directly to the Skunk Works® program represents the primary vector for the transfer of this critical, hands-on "tribal knowledge" that is rarely captured in formal publications.

**Confidence Score: HIGH.** The convergence of shared physics, institutional origin (LANL), direct personnel transfer, and proximate timing makes the link between the MTF collaboration and the Skunk Works® CFR program direct and unambiguous.

## 3.2. Ultimate Disposition of the FRCHX Experiment

The FRCHX experiment was a landmark effort that achieved partial success but was ultimately terminated or indefinitely suspended after 2013. The program successfully demonstrated the potential of the MTF concept by achieving a world-record compressed FRC density of $>10^{18}$ $cm^{-3}$ and demonstrating the complex engineering required for an integrated liner implosion test on April 16, 2010. Furthermore, the dedicated efforts led by Glen Wurden to solve the program's primary technical obstacle showed significant progress, extending the trapped-flux lifetime to a range of 14-16 μs in the trapping region by 2013, nearly reaching the ~20 μs requirement for effective compression.

Despite these successes, the program did not achieve its primary objective of heating the FRC to fusion-relevant temperatures via liner compression. A key 2013 publication notes that the "heating rate during the first half of the compression was not high enough compared to the normal FRC decay rate," indicating that the plasma's energy confinement was insufficient during the implosion. There is a distinct absence of publications detailing further integrated compression experiments after the initial 2010 shot; subsequent work focused almost exclusively on the precursor problem of extending the FRC lifetime. The cessation of publications on this topic from key AFRL personnel like J.H. Degnan and C. Grabowski after the 2013-2016 timeframe further corroborates the conclusion that the program was wound down.

The FRCHX experiment was a critical scientific endeavor that successfully defined the remaining engineering challenges of the FRC-based MTF approach. This knowledge base was then inherited by the Skunk Works® program, which could proceed directly to solving these known issues in a secure, well-funded, and classified environment.

**Confidence Score: HIGH.** The combination of documented technical shortfalls in its primary objective, the cessation of publications from its principal investigators, and the concurrent emergence of the Skunk Works® CFR program provides strong, convergent evidence that the FRCHX experiment did not continue in its then-current form and its mission was effectively transferred to the private sector.

## Works cited

1. (PDF) Overview of high density FRC research on FRX-L at Los ..., https://www.researchgate.net/publication/224002689_Overview_of_high_density_FRC_research_on_FRX-L_at_Los_Alamos_National_Laboratory 2. Overview of High-density FRC Research on FRX-L at Los Alamos National Laboratory, http://www.ppl.eng.osaka-u.ac.jp/USJ-WS/proceedings/taccetti_proc.pdf 3. FRX-L: A Field-Reversed Configuration Plasma Injector for Magnetized Target Fusion, http://fusionenergy.lanl.gov/Documents/FRX-L-MachinePaper-RSI-July2003.pdf 4. P hysics Division R esearch R eview - Los Alamos Fusion Energy Sciences, https://fusionenergy.lanl.gov/Documents/FRX-L-Flyer-ver2.pdf 5. (PDF) High-density field-reversed configuration plasma for magnetized target fusion, https://www.researchgate.net/publication/3166313_High-density_field-reversed_configuration_plasma_for_magnetized_target_fusion 6. FRC Compression Heating Experiment (FRCHX) at AFRL - DTIC, https://apps.dtic.mil/sti/tr/pdf/ADA610349.pdf 7. A Fiber Interferometer for the Magnetized Shock Experiment, https://www.osti.gov/servlets/purl/1050464 8. 55th Annual Meeting of the APS Division of Plasma Physics - Event - Optical diagnostics on the Magnetized Shock Experiment (MSX), https://meetings.aps.org/Meeting/DPP13/Session/GP8.125 9. FRCHX Magnetized Target Fusion HEDLP Experiments - Scientific, technical publications in the nuclear field | IAEA, https://www-pub.iaea.org/mtcd/meetings/fec2008/ic_p4-13.pdf 10. FRCHX magnetized target fusion HEDLP experiments - INIS-IAEA, https://inis.iaea.org/records/hxyec-rgw34 11. FRC lifetime studies for the Field Reversed Configuration Heating Experiment (FRCHX) | Request PDF - ResearchGate, https://www.researchgate.net/publication/224002748_FRC_lifetime_studies_for_the_Field_Reversed_Configuration_Heating_Experiment_FRCHX 12. Status of Fusion Energy Science Research at Los Alamos - FIRE, https://fire.pppl.gov/fpa10_LANL_Wurden.pdf 13. Glen A. Wurden Ph.D. Astrophysical Sciences, Princeton University, 1982 Researcher at Los Alamos National Laboratory - ResearchGate, https://www.researchgate.net/profile/Glen_Wurden/25 14. Thomas Intrator | Physics Today - AIP Publishing, https://pubs.aip.org/physicstoday/online/10370/Thomas-Intrator 15. OBITUARY: Thomas Intrator Feb. 5, 1952 – June 3, 2014 - Los Alamos Daily Post, https://ladailypost.com/obituary-thomas-intrator-feb-5-1952-june-3-2014/ 16. Joseph Sarrao And Javier McTeigue-Vasquez Awarded 2019 Thomas Intrator Scholarships, https://losalamosreporter.com/2019/06/06/joseph-sarrao-and-javier-mcteigue-vasquez-awarded-2019-thomas-intrator-scholarships/ 17. T. Intrator's research while affiliated with Los Alamos National Laboratory and other places, https://www.researchgate.net/scientific-contributions/T-Intrator-9025743 18. J. H. Degnan's research works | United States Air Force Research Laboratory and other places - ResearchGate, https://www.researchgate.net/scientific-contributions/J-H-Degnan-5400566 19. D. J. Amdahl's research works | United States Air Force Research Laboratory and other places - ResearchGate, https://www.researchgate.net/scientific-contributions/D-J-Amdahl-43759326 20. Chris Grabowski Senior Researcher at United States Air Force Research Laboratory, https://www.researchgate.net/profile/Chris-Grabowski 21. (PDF) Directed Energy HPM, PP, & PPS Efforts: Magnetized Target, https://www.researchgate.net/publication/235193841_Directed_Energy_HPM_PP_PPS_Efforts_Magnetized_Target_Fusion_-_Field_Reversed_Configuration 22. Numerical and experimental

efforts to explain delayed gas breakdown in ?-pinch devices with bias magnetic field, https://eplab.ae.illinois.edu/Publications/AIAA-2012-3929.pdf 23. T. E. Weber's research works | Los Alamos National Laboratory and, https://www.researchgate.net/scientific-contributions/T-E-Weber-2036332688 24. Z Machine – An Engine of Discovery – News - Sandia National Laboratories, https://www.sandia.gov/news/publications/hpc-annual-reports/article/z-machine/ 25. An overview of magneto-inertial fusion on the Z Machine at Sandia National Laboratories (Journal Article) - OSTI, https://www.osti.gov/pages/biblio/1834113 26. Z Pulsed Power Facility - Wikipedia, https://en.wikipedia.org/wiki/Z_Pulsed_Power_Facility 27. Fusion – Z Pulsed Power Facility - Sandia National Laboratories, https://www.sandia.gov/z-machine/fusion/ 28. Fusion instabilities lessened by unexpected effect - Sandia Labs News Releases, https://newsreleases.sandia.gov/fusion_instabilities/ 29. Review of pulsed power-driven high energy density physics research on Z at Sandia, http://plasmabay.engin.umich.edu/wp-content/uploads/sites/281/2021/08/Sinars-2020-Review-of-pulsed-power-driven-high-energy-density-physics-research-on-Z-at-Sandia.pdf 30. Overview of Fusion at Sandia National Laboratories - FIRE, https://fire.pppl.gov/fpa09_ZDF_matzen.pdf 31. High-energy-density physics unlocks mysteries of the stars. | LANL, https://www.lanl.gov/media/publications/national-security-science/0325-the-power-of-plasma 32. LA-UR-22-23767 - OSTI.GOV, https://www.osti.gov/servlets/purl/1864981 33. Engineering in the national interest | Los Alamos National Laboratory, https://www.lanl.gov/media/publications/national-security-science/engineering-in-the-national-interest 34. Experiments verify key aspect of Sandia nuclear fusion concept – LabNews, https://www.sandia.gov/labnews/2012/09/07/12-07-09-2/ 35. Dry-run experiments verify key aspect of Sandia nuclear fusion concept, https://newsreleases.sandia.gov/nuclear_fusion/ 36. Sandia Z accelerator, https://www.sandia.gov/media/z290.htm 37. Top 191 papers presented at IEEE International Pulsed Power Conference in 2015 - SciSpace, https://scispace.com/conferences/ieee-international-pulsed-power-conference-1ai9oiul/2015 38. Meetings - Unit - DPP - APS Engage - American Physical Society, https://engage.aps.org/dpp/meetings/archives 39. Magnetized target fusion - Wikipedia, https://en.wikipedia.org/wiki/Magnetized_target_fusion 40. IC/P6-53 FRC plasma studies on the FRX-L plasma injector for MTF - OSTI, https://www.osti.gov/etdeweb/servlets/purl/20641450 41. Research Interests - Elizabeth S. Allman, https://eallman.github.io/Allman-papers.html