(NASA)

CONCEPT PAPER:

RATIONALE, OBJECTIVES, AND ESTABLISHMENT OF A COMMERCIAL APPLIED PLASMA TECHNOLOGY LABORATORY IN ILLINOIS

ARES INSTITUTE

AEROSPACE RESEARCH & ENGINEERING SYSTEMS INSTITUTE

DRAFT

March 1, 2023

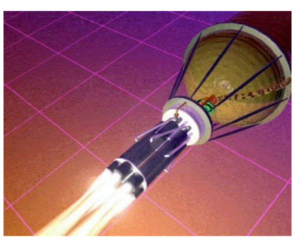
RESPECTFULLY SUBMITTED:

Matthew Travis, CEO
Aerospace Research & Engineering Systems Institute, Inc.
5815 W 6th Ave, Unit 2D
Lakewood, CO 80214
matthew.travis@aresinstitute.org
http://www.aresinstitute.org

ARES Institute, Inc.
5815 W 6th Ave, Unit 2D
Lakewood, CO 80214

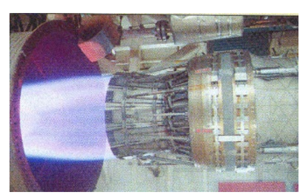
ARES INSTITUTE

CONTENTS



"...In what distant deeps or skies burnt the fire of thine eyes? On what wings dare he aspire? What the hand dare seize the fire?"
-*William Blake* [1794]

"For I Dipp'd into the future, far as human eye could see, Saw the Vision of the world, and all the wonder that would be; Saw the heavens fill with commerce, argosies of magic sails, Pilots of the purple twilight, dropping down with costly bales...."
-*Alfred, Lord Tennyson* [1842]



INTRODUCTION

Throughout the first quarter of the 21st Century, technology for the creation, manipulation, and use of charged plasmas has been evolving as dramatically as electro-technology did over the course of the last. Electricity had been known, studied, and used for over one hundred years before the first commercial power system went online in Niagara Falls in 1897. Since then, however, myriad manifestations of electro-technology have transformed our lives, more than over any previous century in recorded history. It is likely that by the end of this century, plasma technology will have revolutionized our world as did electrification. Plasma applications already pervade the technology base of our civilization, performing critical roles in every discipline. The most obvious and dramatic opportunities for new plasma engineering work include:

- ***Next Generation Radiofrequency Antenna Architectures***
- ***Advanced Laser/Maser Systems Development***
- ***High Performance Aerospace Power & Propulsion***
- ***Controlled Nuclear Fusion & Alternative Energy***
- ***Mineral Refining***
- ***Materials Science & Industrial Processing***
- ***Pollution Control***
- ***Waste Remediation & Resource Recovery***

In a report earlier this century, *"**Plasma Science: From Fundamental Research to Technological Applications**"*, the National Research Council analyzed the importance of and requirements for revitalizing American research into plasma phenomena and applications. A synopsis of the report follows:

SUMMARY

Plasma science is the study of the ionized states of matter. Most of the observable matter in the universe is in the plasma state. Plasma science includes plasma physics but aims to describe a much wider class of phenomena in which, for example, atomic and molecular excitation and ionization processes and chemical reactions can play significant roles. The intellectual challenge in plasma science is to develop principles for understanding the complex macroscopic behavior of plasmas, given the known principles that govern their microscopic behavior.

Plasmas of interest range over tens of orders of magnitude in density and temperature-from the tenuous plasmas of interstellar space to the ultradense plasmas created in inertial confinement fusion, and from the cool, chemical plasmas used in the plasma processing of semiconductors to the thermonuclear plasmas created in magnetic confinement fusion devices. A healthy plasma science enterprise can be expected to make many important contributions to our society for the foreseeable future. The purpose of this report is to provide guidance regarding the ways in which plasma science can contribute to society and to recommend actions that will optimize these contributions.

FINDINGS

1. *Plasma science impacts daily life in many significant ways. It plays an important role in plasma processing, the sterilization of medical products, lighting, and lasers. Plasma science is central to the development of fusion as an energy source, high-power radiation sources, intense particle beams, and many aspects of space science.*

2. *Plasma science is a fundamental scientific discipline, similar, for example, to condensed-matter physics. This fact is apparent when one considers the commonality of the intellectual problems in plasma science that span the wide range of applications to science and technology. Despite its fundamental character, plasma science is frequently viewed in the academic community as an interdisciplinary enterprise focused on a large collection of applications. Experiment, theory, and computation are all critical components of modern plasma science.*

3. *While the applications of plasma science have been supported by the federal government, no agency has assumed responsibility for basic research in plasma science. In general, there is a lack of coordination of plasma science research among the federal agencies.*

4. *As the development of plasma applications has progressed, small-scale research efforts have declined, particularly in the area of basic plasma experiments. This decline has led to a significant backlog of important scientific opportunities. This core activity in fundamental plasma science, carried out by small groups and funded by principal-investigator grants, is dangerously small, considering its importance to the national effort in fusion energy and other applied programs.*

5. *Plasma scientists in academic institutions are less likely to be in tenure-track positions than are other physicists, and courses in plasma science are currently unavailable at many educational institutions.*

CONCLUSIONS

1. *Plasma science can have a significant impact on many disciplines and technologies, including those directly linked to industrial growth. To properly pursue the potential offered by plasma science, the United States must create and maintain a coherent and coordinated program of research and technological development in plasma science.*

2. *Recognition as a distinct discipline in educational and research institutions will be crucial to the healthy development of plasma science.*

3. *There is no effective structure in place to develop the basic science that underlies the many applications of plasmas, and if the present trend continues, plasma science education and basic plasma science research are likely to decrease both in quality and quantity. If nothing is done by*

the federal government, it is likely that research in basic plasma science will cease to exist, and progress in the applications that depend on it will eventually halt.

4. *The future health of plasma science, and hence its ability to contribute to the nation's technological development, hinges on the revitalization of basic plasma science and, in particular, on the revitalization of small-scale basic plasma experiments. With regard to theory and modeling, although the current programs have been successful, there is a need for individual-investigator-led research on questions fundamental to basic plasma science.*

5. *Coordination of research efforts is vital, to make the most effective use of resources by maintaining complementary programs and to ensure that all critical problems are addressed.*

6. *Because of the commonality underlying all areas of plasma science, renewed emphasis on basic plasma science will benefit all areas. Therefore, it is appropriate that redistribution of funding to support basic plasma science come from all areas of plasma science.*

RECOMMENDATIONS

1. *To reinvigorate basic plasma science in the most efficient and cost-effective way, emphasis should be placed on university-scale research programs.*

2. *To ensure the continued availability of the basic knowledge that is needed for the development of applications, the National Science Foundation should provide increased support for basic plasma science.*

3. *To aid the development of fusion and other energy-related programs now supported by the Department of Energy, the Office of Basic Energy Sciences, with the cooperation of the Office of Fusion Energy, should provide increased support for basic experimental plasma science. Such emphasis would leverage the DOE's present investment in plasma science and would strengthen investigations in other energy-related areas of plasma science and technology.*

4. *Approximately $15 million per year for university-scale experiments should be provided, and continued in future years, to effectively redress the current lack of support for fundamental plasma science, which is a central concern of this report. Furthermore, individual-investigator and small-group research, including theory and modeling as well as experiments, needs special help, and small amounts of funding could be life-saving. Funding for these activities should come from existing programs that depend on plasma science. A reassessment of the relative allocation of funds between larger, focused research programs and individual-investigator and small-group activities should be undertaken.*

ARES Institute, Inc.
5815 W 6th Ave, Unit 2D
Lakewood, CO 80214

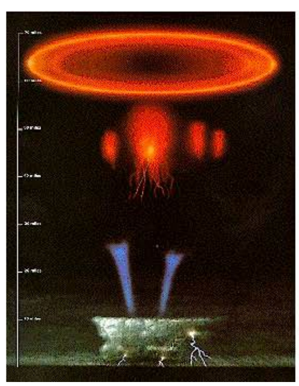
5. *The agencies supporting plasma science should cooperate to coordinate plasma science policy and funding.*

6. *Members of the plasma community in industry and academe should work aggressively for tenure-track recognition of plasma science as an academic discipline, and work with university faculty and administrators to provide courses in basic plasma science at the senior undergraduate level.*

Additional recommendations regarding specific areas of plasma science are made in the main text of the report, available here: https://nap.nationalacademies.org/catalog/4936/plasma-science-from-fundamental-research-to-technological-applications.

As a result of the NRC study, funding for plasma related experimental research has significantly increased since 2000. The National Science Foundation, NASA, and the Departments of Defense and Energy have initiatives to foster the development of new technologies for terrestrial power as well as near and deep space exploration power and propulsion applications. Of great interest are programs sponsored by NASA's Space Technology Mission Directorate and Office of Chief Technologist which are intended to mature "game-changing" technologies for space exploration. There are periodic funding opportunities through the System for Award Management, SAM.gov, (https://sam.gov) and the NASA Solicitation and Proposal Integrated Review and Evaluation System (https://nspires.nasaprs.com) which are available to support research in this field. These include the Stand-alone Missions of Opportunity (SALMON) solicitation as well as solicitations in the materials science field.

Additionally, NASA's Strategic Framework (https://techport.nasa.gov/framework) lays out NASA's vision for the future of space exploration across a range of disciplines, including advanced power, propulsion, and spacecraft technologies. We intend to submit proposals to the aforementioned government agencies as well as pursue other federal, state, foundation, and corporate grants as well as contracts and other sponsorship.



RATIONALE

An interdisciplinary applied plasma technology research program in collaboration with a higher-level institution in Illinois would bring together several elements of work already being done, or previously having been done by university scientists, creating a 'critical mass' able to attract more substantial funding in the future than such efforts have historically, on an individual basis. It would broaden the appeal of the school's programs in Electrical Engineering and Physics, in particular, expanding their focus beyond concentrations in computing-related electronics, applied imaging, astrophysics, and high energy particle studies, respectively. Finally, it would establish a path and vehicle for commercialization of research results into the industrial base of the United States and globally.

Indeed, the primary goal of the laboratory proposed herein is to bridge the gap between university and other publicly funded research and the commercial sector. There are many concepts that have been researched in a laboratory setting and matured to the stage that they are ripe for development into commercial products but have been unable to make that leap. This is due to many factors, usually relating to funding or inability to build commercial interest. An R&D laboratory that operates in the space between pure research and commercialization would be able to foster that transition and growth. In contracting terminology, it is analogous to going from an SBIR or NIAC Phase II contract to completing a Phase III and beginning commercialization of the research products.

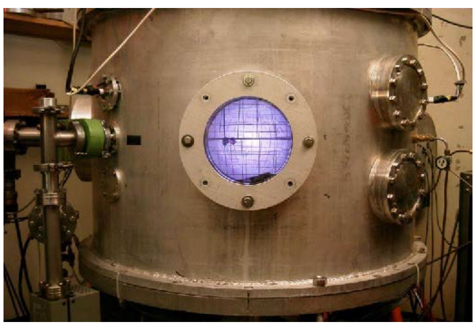
A plasma and fusion technology lab would advance work in CO2 laser electrodynamics, advanced rocket propulsion, alternative energy, semiconductor vapor deposition, and other fields and utilize presently dormant facilities and equipment. It would create a "signature instrument" - a unique research apparatus sufficiently advanced and desirable in its capabilities as to attract top talent from across the country and around the world. In giving laboratory partners access to equipment able to draw prestigious investigators to use it, in addition to assets owned by the university partner, this program will also attract graduate and doctoral students of the highest caliber to work with them, and early career professionals will have a launching pad to further their careers. Early-stage and growth companies in the associated fields will become clients of the laboratory to further development of their own products and services, thereby helping to fund the growth and spectrum of research conducted by the laboratory.

The research facilities would be of immediate benefit and use to professionals and companies working in laser theory, space physics, clean fusion power and propulsion, combustion dynamics, RF antenna architecture, bio-energy, waste reutilization, semiconductor microelectronics, and aerothermodynamics. Its function in support of future work in Electrical Engineering, Physics, Chemistry, Aerospace and Mechanical Engineering will grow over time, providing experimental test-bed infrastructure of great versatility and broad application, in addition to the laboratory's own research program.

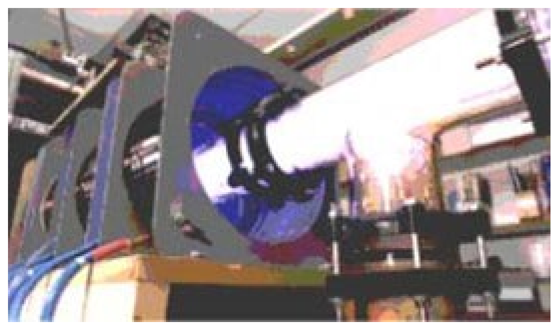
Plasma technology is both visually and viscerally exciting; it offers events, devices, images, and ideas that can captivate undergraduates and donors, in ways that few types of research can match. Intended to represent a higher profile research initiative than any currently on the books on campus, the plasma program will generate a large volume of work for publication in major peer-reviewed journals in several disciplines, through collaboration projects with faculty at other, more prominent universities. Elements of such work will inevitably find their way into the popular media, replete with stunning photographs of leading-edge work on important problems, and hopefully, important solutions.

Over the past several decades, a significant amount of plasma and fusion research has been conducted at university institutions around the world. Examples of plasma research include University of Wisconsin: Fusion Technology Institute, University of Canberra: Plasma Instrumentation Laboratory, and Texas Tech University: Plasma and Pulsed Power Program.

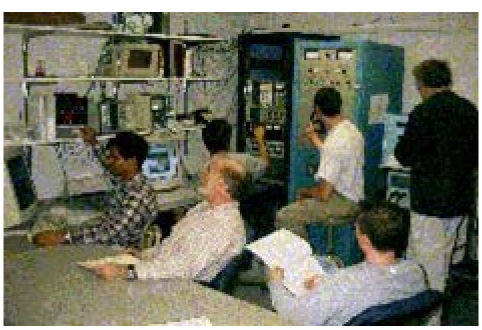
Of particular significance are the Wisconsin Fusor (*below, left*) and the Canberra Helicon (*below, right*), their "signature instruments", which gave these institutions high prominence in the field of plasma research.



Outer Containment of UW Fusor



UC Helicon Modulated for RF Communications

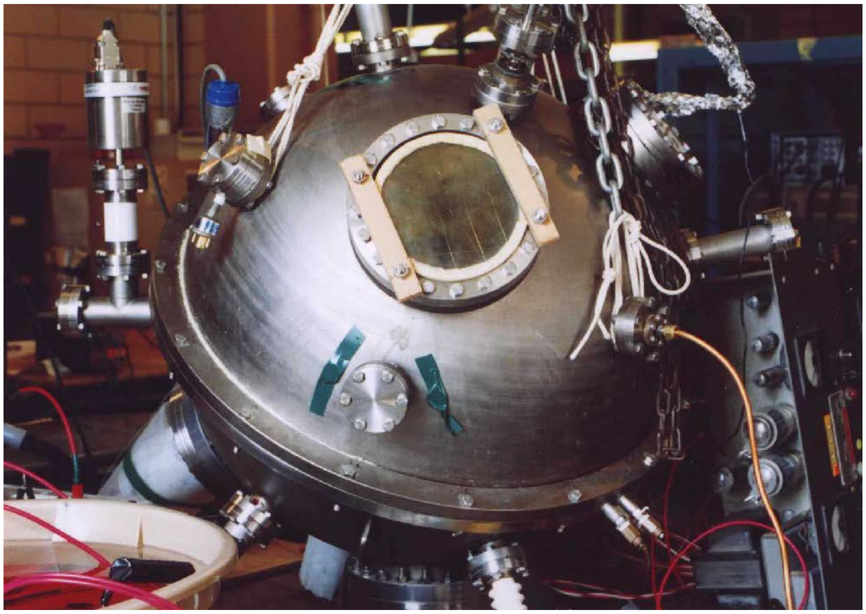


IEC Team of the Fusion Technology Institute at University of Wisconsin

Helicon at University of Canberra Plasma Instrumentation Lab

However, those programs have since concluded and there is currently a gap in this research field that is primed for new laboratories and organizations to fill.

Research is ongoing at the University of Illinois, specifically within the Department of Nuclear, Plasma, and Radiological Engineering (https://npre.illinois.edu) which creates an opportunity to establish a public-private partnership in order to both conduct fundamental scientific research as well as develop applications using results of the research that can be commercialized and propagated through industry.



Previous IEC Fusor apparatus at the University of Illinois

We have a desire to attract the University of Illinois to be our university partner. If a partnership or working relationship with the University is established, it makes most sense for the Department of Nuclear, Plasma, and Radiological Engineering at the University's, Urbana-Champaign campus.

Much of the supporting diagnostics attendant to the primary plasma instruments will be custom designed and built by laboratory staff with, hopefully, help from students in the university; consequently, many of the more in-depth educational opportunities afforded by such a laboratory will accrue largely to the university. While there are numerous undergraduate and graduate courses in several departments which would benefit from the facility's value as an instructional tool, those in electromagnetic fields, lasers, RF, and power systems will be among the most relevant.

INERTIAL ELECTROSTATIC CONFINEMENT (IEC) FUSION: BASICS

Nuclear fusion is the process in which two atomic nuclei fuse together forming a larger nucleus and thereby releasing energy. The heat of the plasma is captured to create steam to turn a turbine. The goal of power-generating fusion reactors is to have the heat of the plasma generate steam that drives a turbine that generates electricity.

Generally speaking, fusion reactor designs can be categorized into two classes that differ in how they contain plasma: magnetic confinement and inertial confinement.

Magnetic confinement uses strong magnetic forces to squeeze a plasma of hot hydrogen to fusion conditions while keeping the plasma from melting the reactor containment. Magnetic confinement reactor designs include toroidal machines, such as the tokamak, stellarator designs, and sphereomak designs. [20]

Inertial confinement takes a different approach to achieving fusion conditions: hydrogen fuel is compressed by means of a strong laser beam. [21] The French Laser Megajoule and the American National Ignition Facility are examples of reactors using this approach. [21]

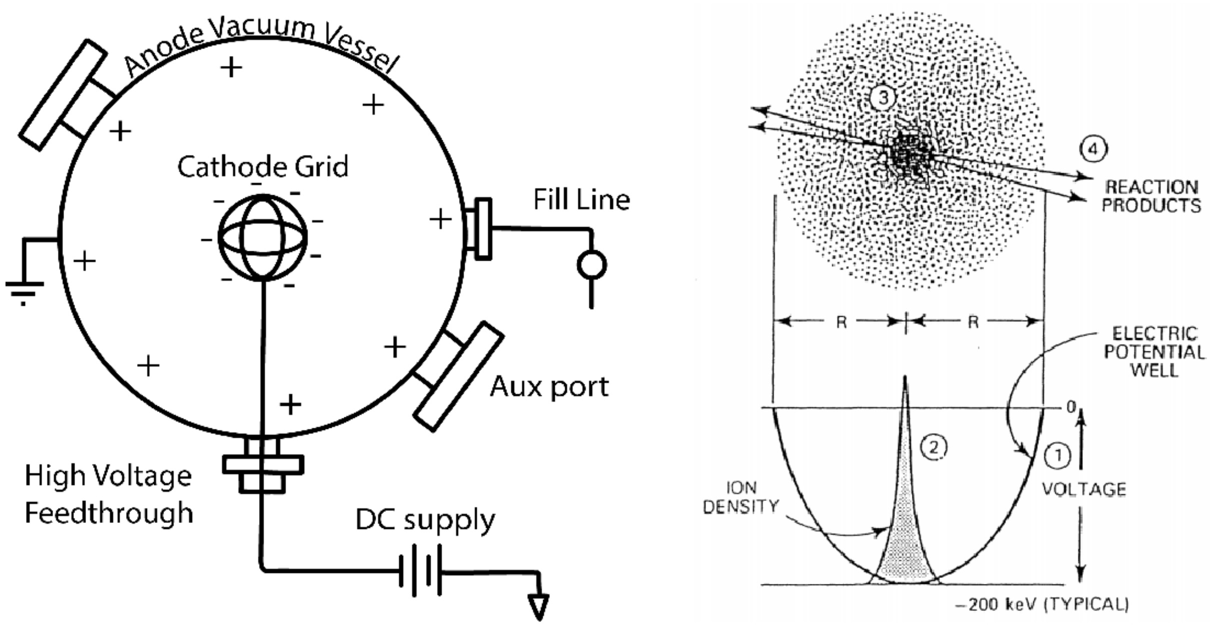
A third type of fusion reactor design, inertial electrostatic confinement, shares some characteristics of magnetic and inertial confinement designs but is unique in others. This is the type of reactor that the laboratory will employ for its research

IEC uses a strong voltage differential to accelerate ions towards the center of a sphere, causing some to collide and fuse. [22] The idea of this mechanism for plasma confinement for nuclear fusion was first introduced in a scientific paper by Elmore et al. [22] Their proposal consists of a chamber that is first pumped to a near vacuum. Inside the chamber are two concentric, spherical metal "grids". The outer grid is grounded, while the inner grid is given a very high voltage. This creates an extreme voltage differential between the two grids. Into this, hydrogen gas is introduced. The voltage differential between the grids causes the electrons on the hydrogen atoms to be stripped off and attracted to the outer, more positive grid. The remaining positive hydrogen nuclei are accelerated towards the inner grid, pass through it, and have a chance of colliding in the center and fusing. If positive nuclei do not collide, they pass through the center, decelerate, then fall back towards the center. These oscillations can repeat many times, increasing chances of a collision. [22] The potential difference between the two grids is maintained, keeping the separation between the positive ions and electrons.

The ionization of hydrogen and concentration of ions at the center of the reactor create visible plasma. The ultimate objective is to concentrate this plasma to an ion density that supports enough fusion to generate heat that exceeds the energy needed to maintain the reaction. This is necessary in order to achieve net positive energy production for power systems. However, there are many applications of IEC fusion that do not require this.

From Wikipedia:

"The IEC fusion device is a spherical vacuum vessel (pumped to < 10-6 Torr) that uses quasi-spherical polyhedral magnetic fields to confine electrons, which are injected into the vessel at high energy, in order to form a negative electric potential well that confines fusion ions in a spherically-converging flow. Energetic fusion ions are generated by a plasma discharge and then injected into the potential well near its boundary, where they are accelerated radially inward towards the center and oscillate across the vessel with the central core plasma density increasing rapidly as r-2 (towards the center)."



High-level schematic of an IEC fusor device.

“As the ions converge at the center of the vessel, they form a dense central plasma core region where fusion occurs, resulting in an extremely high fusion power density. The ions reach maximum density at a core radius set by the ratio of their initial transverse energy at injection, to their energy at the core boundary (radius rc). Bussard and Jameson (1995) report that typical ion convergence ratios are 0.001 < <rc> < 0.01 (<rc> = averaged core boundary radius), thus yielding a core densification of 104 – 106 times above the minimum ion densities (near the edge of the polyhedral magnetic surface) in the system. Any unburned fuel is recycled through the vacuum system."

"Direct production of high-voltage electrical power is by the deceleration of charged fusion product ions in an externally imposed electric field. The product ions escape from the central plasma core predominantly along radial (micro-channel) paths and can be collected, as they approach zero kinetic energy, by potential-biased grids placed at appropriate radial positions along their path (Bussard and Froning). The grid collectors are connected to the electrical circuit driving current through the system external load. The output power generated by this process will appear as modest DC currents (kA) at high voltages (typically 0.5 – 2.24 MV).”

“The feasibility of this direct conversion scheme has been proven by previous experimental research (Moir and Barr, 1973; Barr and Moir, 1983). Bussard and Froning (1998) report that the direct conversion process is nearly 100% efficient. Miley et al. (1995) describe experiments which show that the fraction of ions intercepting the collector grid wires is greatly reduced by using a particular grid geometry that has a 97% effective transparency to the radial micro-channel ion flows, thereby greatly improving grid wire lifetime and performance."

OBJECTIVES

- To substantially broaden the funded research base through collaboration with other science and engineering organizations, university departments, and private companies also desirous of new starts, targeting manifest federal interest in plasma and fusion related experimentation.

- To augment and compliment previous, ongoing, and future anticipated work in several areas that could benefit from plasma technology requirements or development, [including but not limited to IEC and ion rocket propulsion, semiconductor vapor deposition, multimodal gas laser excitation, photokinetic dynamics, and waste hydrocarbon reformation] evolving such work toward practical fruition in contractually supported experimental hardware.

- To craft and demonstrate a unique "signature instrument" and developing a world-class center for a broad range of into applications of plasma and fusion technology able to attract top talent from industry and academia, including at the undergrad and graduate level, through its singular technical capabilities to more conveniently and cost-effectively conduct key experiments than any competing facility.

- To provide robust, generic research assets in engineered plasma systems able to support a wide variety of investigations of opportunity for which funding may become available in the future, through a dedicated program of foundation grants proposal writing, through the continuing activity of other faculty, or through serendipitous discoveries or experimental requirements which arise unexpectedly across the cognizant disciplines.

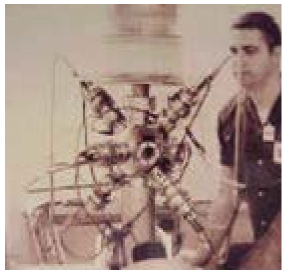
- To develop mechanisms for instructional support for existing courses in Electrical Engineering, Physics, Space Sciences, Space Systems, Aerospace Engineering and Chemistry which cover plasma related phenomenology, and the proctoring and support of graduate or doctoral students pursuing plasma related research, perhaps leading to the eventual compilation of a pioneering core curriculum in Plasma Technology.

- To assemble a user-friendly Single Point of Contact for industrial firms with plasma technology development requirements and related materials science issues, providing one-stop-shopping for relevant goal-directed, sponsored corporate research contracts, and a mechanism to represent and market commercially viable capabilities and products to the Illinois manufacturing sector, statewide, through an existing network of on-site Applications Engineering consultants.

ARES Institute, Inc.
5815 W 6th Ave, Unit 2D
Lakewood, CO 80214

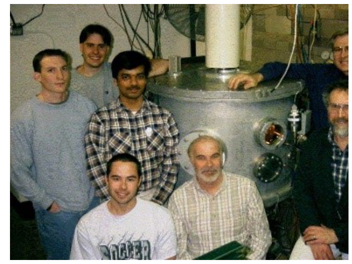
- To create a pathway for the commercialization of foundational research in plasma and fusion sciences through R&D into applications, use-cases, and potential commercial product prototyping and demonstration.

1950s: Farnsworth at ITT
*10*8 Neutrons/Sec*



1970's Hirsch Fusor
10^9 Neutrons/Sec

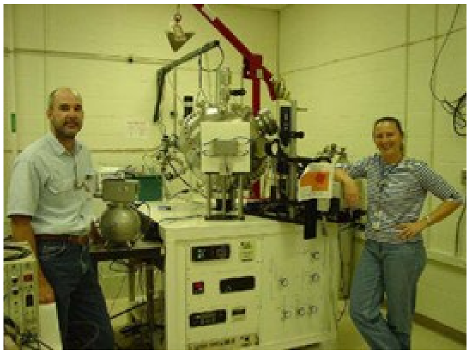
1980's Hirsch Fusor
10^10 Neutrons/Sec



2001: Univ of Wisconsin
*10*11 Neutrons/Sec*

GOALS

1. Within 12 Months:
    a. Relocate ARES Institute to Illinois.
    b. Generate a minimum of $500,000 in grants, contracts, bequests, endowments, donations, and sponsored research in the first 12 months of operation.
    c. Complete establishment of Plasma Technology Lab.
    d. Hire a full-time Laboratory Director with experience in a relevant field.
    e. Fabricate/Assemble/Construct initial research instrumentation.
    f. Initiate support for 3 M.S.-candidate thesis research projects.
    g. Complete and submit a minimum of 2 STTR and 2 SBIR proposals to NASA, DoD, NSF, and/or DoE.
    h. Complete and submit a minimum of 1 NASA NIAC proposal.
    i. Submit 2 papers for publication in peer-reviewed journals.
2. Within 24 Months:
    a. Recruit and initiate support for 1 PhD-candidate dissertation research project.
    b. Document and publish 3 scientific papers in peer-reviewed journals.
    c. Achieve Phase I (D+D) Activation of the IEC Reactor, with Telescience Support
    d. Generate a minimum of $2,000,000 in grants, contracts, bequests, endowments, donations, and sponsored research.
    e. Supplemental site preparation for new equipment chambers.
    f. Continue support for first 3 grad students, add 2 new starts.
3. Within 36 Months:
    a. Continue support for first doctoral student, add another.
    b. Provide funding for one full-time Visiting Research Professor .
    c. Publish an additional 6 papers, with presentation at major conferences.
    d. Host workshops on selected plasma issues.
    e. Demonstrate an IEC fusion rocket thruster intended for an orbital flight test.
    f. Upgrade to Phase II Activation of the Reactor, using Advanced Fusion Fuels.



Fusor apparatus at NASA's Marshall Spaceflight Center

Fusor Built by Dr. Hal Puthoff, Institute for Advanced Studies at Austin

ORGANIZATION

To be known as the "***Space, Plasma, High-energy Electrostatics Research & Engineering Laboratory***", or "**SPHERELAB**", the proposed facility is a joint effort by ARES Institute and Institute and Interstellar Exploration Concepts, IEC Inc., (see below) and will engage academic and industrial research clients as well as perform government or foundation sponsored plasma research. It will establish a distinct identity as a Center of Excellence for plasma and high-energy physics and applications. Mr. Matthew Travis will serve as the initial Director of the laboratory with a commitment to hire a full-time Director with significant relevant experience as soon as practical and within the first year of establishment of the laboratory.

SPHERELAB will be jointly owned by ARES Institute and IEC Inc. and primarily managed and operated by ARES Institute. Funds for the laboratory will be raised by both ARES Institute and IEC Inc. with the cost of operations being shared between the two entities based on utilization. ARES Institute will be the Point of Contact for third-party non-commercial clients and users of the lab's assets. IEC Inc. will utilize the facilities to conduct its own funded research and commercial activities and will reimburse ARES Institute for support costs. This organizational relationship will enable SPHERELAB to pursue both SBIR and STTR contracts from federal agencies.

.

To help bring distinction to SPHERELAB, an external Advisory Board of experts outside both ARES Institute and the university partner from industry, nonprofit research institutions, and government will be formed to provide a liason to other institutions with whom cooperative projects are likely to be undertaken.

To support the day-to-day management of the laboratory, we propose to organize a Steering Committee for the laboratory, selecting representatives with experience in academic, industry and government sectors in the Electrical, Mechanical, Aerospace, Environmental, Chemical Engineering, Physics, Space Sciences, and Chemistry disciplines. These individuals will be recruited based on their research interests that intersect with the aims of the facility, and their willingness to collaborate, and contribute effort toward bringing it to fruition.

We intend to engage a market research firm to conduct interviews with selected universities and corporate researchers nationwide, as to their relative interest in using the anticipated facilities of the proposed Plasma Technology Laboratory. Such an outlay, while not fundable under the financial support to be sought to construct the lab, would nevertheless provide valuable intelligence as to the lab's intermediate and longer-term prospects as a magnet for funded research, and the future recruitment of faculty, doctoral candidates, and grad students desirous of pursuing plasma research objectives. This will be supplemented by a robust presence on social media, public presentations, media interview and podcasts, etc.

Once authorized, the lab will have the opportunity to engage vendors of high technology industrial manufacturing equipment and technical support services, to discuss the lab's plasma technology consulting capabilities with its customer base. Regularly calling on hundreds of manufacturing firms throughout Illinois, the supplier can distribute literature and interactive presentations targeted at industrial process problem solving in the plasma technology arena. These manufacturers support aerospace and defense prime contractors having specialized fabrication requirements. Techniques in such areas as Wire Electron Discharge Machining, Laser Ablation, Surface Coating Deposition, and even Jet Turbine Noise Suppression all require continued scientific and engineering investigation into plasma generation, characterization, and phenomenology. With the support of such an industrial partner, SPHERELAB can become a source of compensable consulting expertise to Illinois manufacturers with mission-critical plasma technology issues to resolve.

FACILITIES

The ideal locations for the plasma technology laboratory would be either a new facility designed specifically for high-energy research and the fusor apparatus or a vacant facility that has previously been used for aerospace, laser and/or high energy research. The facility should be located on or adjacent to a university campus or at a supportive R&D industrial park. One potential location could be the University of Illinois Research Park (https://researchpark.illinois.edu/).

Optimally, the facility would be insulated against stray radio and electromagnetic interference. Offering features of safety and security, a windowless, steel reinforced, lead lined concrete structure incorporates inherent protection from any transient neutron/gamma radiation or explosive chemical anomalies that might arise as a consequence of the anticipated research.

An example of a potential architectural concept, the laboratory could incorporate an underground "Cave & Pit" design, similar to those employed by Dr. Farnsworth and his team at ITT where the first IEC Fusor devices were built and tested originally.

Financial support that we are currently raising will be used in part to initiate the creation of new and/or refurbish existing laboratory facilities. The building should be able to be outfitted, if necessary, with essential power conditioning equipment close to where the high voltage supply enters the building, with minimal rewiring or disruption to other facilities.

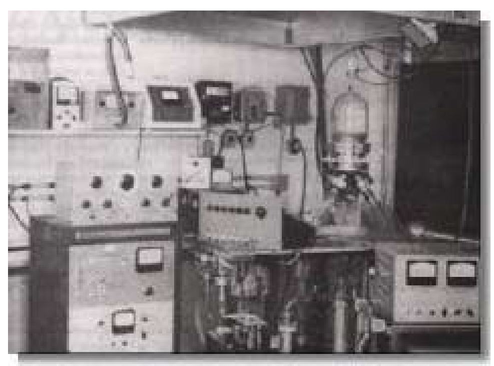
The lab will require proximity to high-throughput broadband internet services to enable easy access to high data rate data communications, where multichannel, high resolution streaming data and video of ongoing experiments in real-time need be furnished to collaborating researchers at other institutions, without saturating internal network circuits. Exploiting this capability to provide real-time remote interaction with the lab's primary instruments to offsite researchers is a principal component in the strategy to establish a substantive identity for the lab in its field.

If located in a pre-existing building, a detailed radiological examination of the facilities will be carried out, to identify and quantify any low-level electromagnetic radiation, and a thorough cleaning and sealing of the building's structure will be performed.

A proposed hallmark of the facility will be a small, aesthetically designed combined conference room and visitor gallery with exhibits and display monitors with discrete digital sound, able to comfortably seat 25-50 people. Adjacent to a state-of-the-art control center, this would provide a safe, external, theatrical viewing opportunity for students and others to observe spectacular plasma experiments in progress and would be useful for related instructional purposes and public relations endeavors. During laboratory down time, file footage or other university programming could be presented. When live, the video stream can be simulcast on the Web, and offered to various news media outlets as B-Roll material.

The laboratory will arrange for maximum use of volunteer labor to perform the laboratory refurbishment at minimal cost other than for materials (which may ultimately be donated).

Inexpensive Benchtop Inertial Electrostatic Confinement Demonstration & Test Cell



Fusor at ITT Lab (c.1958): Instrumented with Vacuum Tubes, Reactor Core Descends into Pit

EQUIPMENT

Initially, the Plasma Technology Lab will be built around three important, primary, high-energy instruments and a plethora of smaller devices suitable for the conduct of a wide variety of less intensive plasma operations. It is anticipated that M.S. Thesis and PhD Dissertation research to be supported by the lab will revolve around the design, construction, and operation of additional scientific machines and diagnostics, which will, in time, become a part of the lab's permanent capabilities manifest. Other equipment would include vacuum plasma deposition chambers, and commercial devices to experiment with plasma-based surface coating techniques of industrial application.

A centerpiece of the proposed laboratory will be a modern, modular version of ***the Fusor, a Spherical Inertial Electrostatic Confinement (IEC) Reactor*** developed by Dr. Philo T. Farnsworth (the inventor of television) in the 1950s, as refined by Dr. Robert L. Hirsch and Dr. Gene A. Meeks in their 1968 Patent for International Telephone & Telegraph, to whom Farnsworth sold the technology. Known as the "Farnsworth Fusor", it reliably produces D+D, D+T, or D+3He fusion in its central plasma kernel, without bulky lasers, or massive electromagnets, and has been advocated by Drs. Robert Bussard, Robert Forward, and George Miley as one of the best candidate fusion reactor architectures likely to be small enough and light enough for spacecraft power and propulsion applications.

The IEC concept became largely dormant for over two decades in the last half of the 20th Century, but it was later revived and revised by Bussard and coworkers (Bussard, 1989, 1990, 1991, 1992, 1993, 1997; Krall, 1992; Bussard and Jameson, 1993, 1994, 1995; Bussard et al., 1993; Froning and Bussard, 1993, 1998; Froning, 1997; Bussard and Froning, 1998; Watrus et al., 1998; Froning et al., 2001) and Miley and coworkers (Nadler et al., 1992; Miley et al., 1993; Barnes and Nebel, 1993; Miley et al., 1994; Satsangi et al., 1994; Miley et al., 1995; Nadler et al., 2000). It is also of historical interest to note that P. T. Farnsworth is the inventor of television (Everson, 1949). Bussard and Miley and their coworkers discovered a way to configure the IEC device for electric power and space propulsion applications using modern engineering-physics and materials technology.

Fusors built by various universities (University of Wisconsin-Madison Fusion Technology Institute, the University of Illinois at Urbana-Champaign Fusion Studies Laboratory, University of Kyoto Institute of Advanced Energy) as research apparatus, and those built by hobbyists, independent experimenters, and even individual undergraduate students as projects, have consistently produced between 1x10 and 1x108 11 neutrons/sec., evidencing fusion beyond all doubt. A commercial, off-the-shelf version of the device, the FusionStar NG-1, was produced by EADS/Astrium as a safe, portable industrial/scientific neutron source requiring no radioactive material.

The Department of Nuclear, Plasma & Radiological Sciences at the University of Illinois, Urbana-Champaign has been a leader in the field of fusion research for decades. Specifically, the Fusion Studies Laboratory, under the direction of Dr. Miley, has conducted groundbreaking research into the fundamentals and applications of inertial electrostatic confinement fusion. Dr. Miley is also one of the authors of the seminal text on IEC fusion[3].With its long history and deep experience, and being a world leader in IEC fusion research, we believe the University of Illinois would be an ideal collaborator with the privately-owned research and development laboratory described in this paper that would be located in Illinois.

Using the same high voltage power supplies, MHD power extractors, plasma diagnostic sensors, fuel feed plumbing, and external containment as the Fusor, a similarly sized prototype of the Plasmak, another low-cost alternative plasma fusion reactor concept will also be constructed. ***The Plasmak, a Magnetoplasmoid Compression Furnace***, generates autoconfining compound plasma structures ("PMK"s, for 'plasma mantle & kernel') characterized as "artificial ball lightning", which are then surrounded by a noble gas, and subjected to adiabatic, isobaric compression by mechanical means. This pneumatic approach has been theorized for many years to achieve center kernel plasma densities more than adequate to initiate fusion, however, until recently, the enabling technology to reliably induce the magnetoplasmoids to become stable through autoconfinement had not been realized. Experiments on the Prometheus II testbed in College Park, Maryland (Koloc, et al) have documented the evolution of stable PMK magnetoplasmoid structures, with lifetimes of seconds, which are required to initiate the compression phase of reactor operation.

The Plasmak is an elegant approach to aneutronic fusion, with anticipated neutron flux many orders of magnitude lower than the Fusor, at a given power level and rate of fuel consumption. It is intended to burn heavier fusion fuels and can explore plasma density regimes unattainable by any other confinement method, since the autoconfining magnetic fields are self-generated by the plasmoid, there is little external energy input required and no losses or contamination due to wall collisions.

Although no Fusor or Plasmak reactor has ever been reported to reach breakeven (despite substantial investment by ITT in the Fusor in the '50s and '60s, and by BMT/General Atomic in the Plasmak in the '70s and '80s), new theoretical models and technologies for manipulating plasmas which did not exist decades ago may now make that dream a reality. The proposed plasma technology lab will examine these opportunities, among others.

Inertial Electrostatic Confinement and Autoconfining Magnetoplasmoid Compression offer tantalizing opportunities to inexpensively produce controlled plasmas with dense kernel temperatures exceeding 400,000,000 degrees, in devices each no larger than a major household appliance. It is envisioned that through multiple iterations of the Fusor, and the Plasmak, the lab will exhibit greater and greater capability with these instruments, evolving a unique experimental testbed with implications beyond fusion research. Their most exotic and expensive components are the Ion guns (Fusor), and Ignitron tubes (Plasmak) which are commercial off-the-shelf equipment, and the Fusor's central spherical electrode grid. The remainder of the reactor systems are each comprised of ordinary vacuum and pneumatic pumps, high voltage power supplies, and machined stainless steel containment vessels.

The third unique primary instrument sought to round out the lab's potential as a one-of-a-kind Center for specialized plasma research would be a proprietary machine for the analysis of photochemical combusting plasmas. Needed to resolve longstanding energetic anomalies in the reaction kinetics of photochemically active species (such as high Q_e halogenic supercombustors), the proposed ***Quantum Hydromagnetic Induction Assay Spectrometer*** would use sensitive MHD/MPD coils to precisely analyze the plasma output of a photokinetic reaction system (such as a small rocket thruster based on such technology), using known mass flow rates and the charge magnitude to provide insight as to the underlying photokinetic translation mechanism.

Educated to a chemical scrubber by conada effect, the QHIA ("key-ah") Spectrometer will be calibrated with known ion flows from well metered sources to provide precise resolution of the charge flow over several orders of magnitude. It will have broad, generic application to plasma research at the lab, but is specifically required to advance prior research into photokinetic rocket propulsion. Coupled with optical and electromagnetic diagnostics of the reaction chamber itself, significant studies of photochemical combustion can be carried out using this instrument.

The MHD/MPD mechanism required of the Spectrometer would also be used with the Fusor and Plasmak for power take off and exhaust analysis, maximizing the value, efficiency, and utility of the instrumentality incorporated into the lab's design. Its education system can be adapted to recover valuable Deuterium and Helium for recycling and reuse on the premises, reducing overall operating costs. As a result, the major cost elements of equipment infrastructure (same high voltage power supplies, MHD power extractors, plasma diagnostic sensors, fuel feed plumbing, and external containment) can be used to support all three primary instruments, giving the lab unique capabilities not otherwise available collocated in tandem, anywhere in the United States.

FusionStar Plasma Kernel

FusionStar NG-1: Commercial Off-The-Shelf IEC Fusion Reactor by EADS/Astrium

Advanced Fusor Core at University of Wisconsin IEC Lab, Shown without Outer Containment

Plasma Kernel of University of Wisconsin Fusor

POTENTIAL INVESTIGATIONS

The laboratory will undertake difficult, high-risk/high-reward investigations in each of the six principal sectors previously identified in the Objectives, the relative activity and prominence of each dependent upon the degree of external funding that can be developed in that program area.

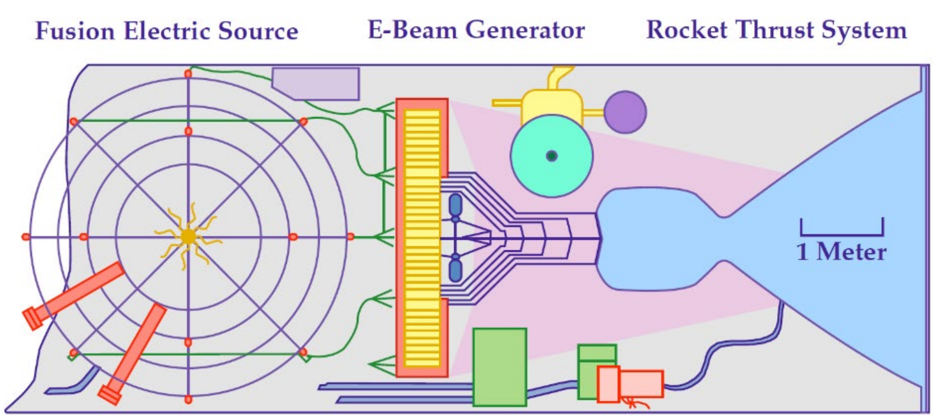
Advancements in Artificial Intelligence and Machine Learning since the turn of the Century, combined with modern High Performance Computing platforms have enabled research in the plasma and fusion sciences far beyond what was possible just a couple decades ago. Equally important, these technological advances enable research to be conducted far more economically than in the past. SPHERELAB will collaborate with our industry and university partners to fully utilize advanced capabilities in AI/ML to stay on the leading edge of science and technology, especially in the development of commercial products and services.

Strategic research starts offering the greatest promise of federal or corporate sponsorship, and eventual commercialization, include the following:

High Performance Power & Propulsion for Deep Space Exploration

The primary focus of the laboratory's work will be research into applications of Inertial Electrostatic Confinement fusion for aerospace applications and the eventual development and commercialization of neutron-free "aneutronic" power and propulsion systems. Fusion is the ideal technology for terrestrial and space-based power systems and high impulse propulsion. It holds the promise of clean energy on Earth and the potential to open the door to truly deep space exploration beyond Earth and even beyond our solar system.

The range of potential applications of Inertial Electrostatic fusion in aerospace is vast. As described by Dr. Robert Bussard in his paper, "Inertial Electrostatic-Fusion Propulsion Spectrum: Air-Breathing to Interstellar Flight"[2], IEC fusion technology has potential in air-breathing hypersonic point-to-point transport, orbital tugs and transfer vehicles in Earth orbit and cislunar space, and rapid transport, both uncrewed and crewed, to Mars and beyond



Concept of a high-thrust IEC-powered rocket engine. From (2).

NASA is cognizant of the opportunities that fusion technology enables. It is true that there is currently a focus on maturing fission-based Nuclear Thermal Propulsion at NASA and other U.S. government agencies in the relative near term. One example is DARPA's DRACO program. However, the long-range vision of NASA includes fusion-powered systems to enable exploration missions that are not possible with chemical, low-thrust electric, or even fission-based nuclear propulsion.

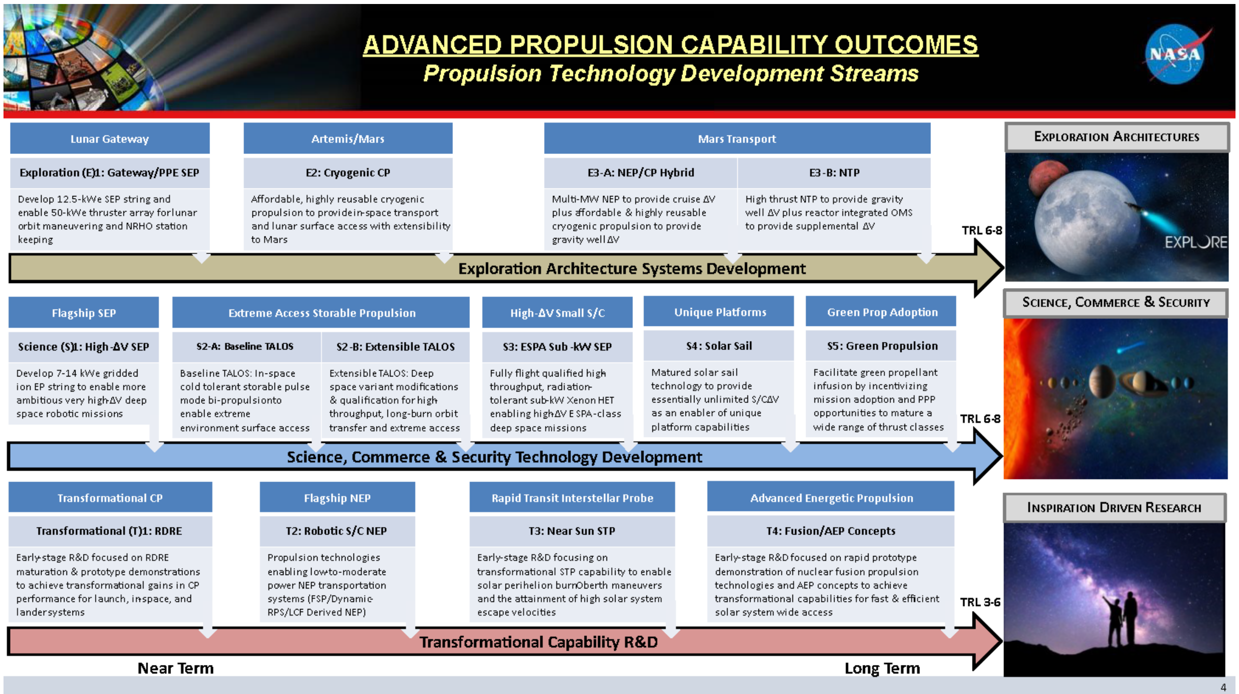
“NASA’s Space Technology Mission Directorate (STMD) utilizes the Strategic Framework to organize its technology investments to address desired outcomes. The NASA STMD Strategic Framework is comprised of Strategic Outcomes spanning 18 technology capability areas. The Strategic Framework is organized into Thrusts that span the areas of concentrated technology investment. Each strategic outcome is elaborated by providing an Envisioned Future that further describes possible futures enabled by achieving this outcome.”

“For each outcome, an Envisioned Future has been developed in pictorial chart format describing a vision which will help identify and define potential technologies necessary for achieving that vision. The Envisioned Future charts are supported by a summary of the state of the art in each capability area and a long-term plan for attaining this Future with tactical next steps highlighted.”

In 2022, NASA released a Request for Information for the “GO Thrust” area seeking information from industry about advanced propulsion technologies for future exploration programs. The scope of the request addresses the broad scope of propulsion technology development requirements in the coming years. The full RFI can be accessed from NSPIRES at:

https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId={457AE2EA-DBB8-7405-C731-FD3B4E52BFC8}&path=open

NASA Space Technology Mission Directorate vision for future advanced propulsion for deep space exploration. Zoom in to view on a computer.



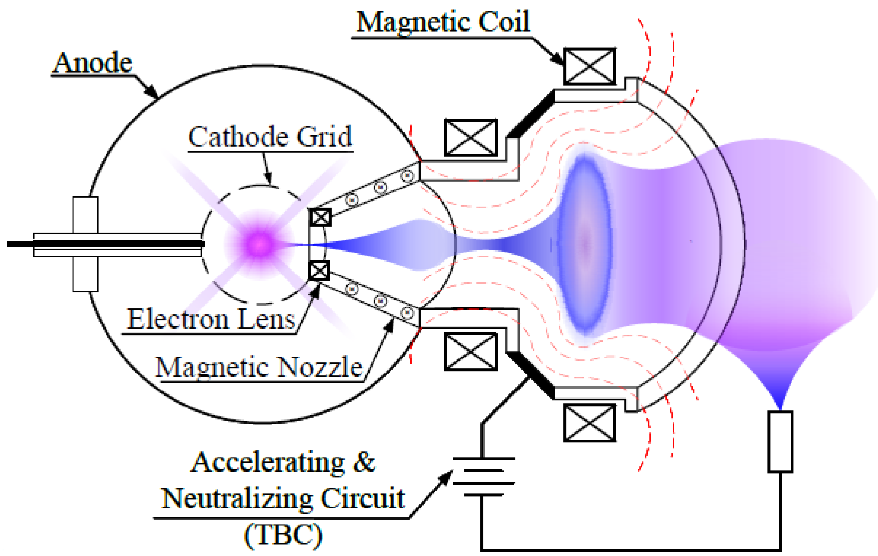
NASA's propulsion technology development streams. Zoom in to view on a computer.

The laboratory will embark on a three-phase research program beginning with the development, fabrication, and in-space demonstration of an IEC fusion electric thruster similar to one proposed by Dr. George H. Miley at the Fusion Studies Laboratory of the University of Illinois. In the introduction to his paper earlier this Century, "Space Probe Application of IEC Thrusters" [1], Dr. George H. Miley and his research team wrote:

"Earlier studies have described Inertial Electrostatic Confinement (IEC) fusion power concepts using either D-He^3 or p-B^{11} fuels to provide a high-power density fusion propulsion system capable of aggressive deep space missions. However, this requires a large multi-GW thruster forcing a long-term development program. As a first step, we examine here a progression of near-term IEC thrusters, starting with a 1-10 kWe electrically-driven IEC jet thruster for satellites followed by a small 50-100 kW IEC fusion thruster module for next generation large deep space spacecraft. The initial electrically-powered unit is a novel multi-jet plasma thruster based on spherical IEC technology using electrical input power from a solar panel. This type of unit is discussed and its advantages for next step electrically driven units are identified."

The paper concludes:

"This paper identifies an orderly progression of IEC applications in commercial space power, starting with an electrically driven IEC thruster. The attractive characteristics of the electrically driven device, namely light weight, low maintenance, low fuel leakage and extreme maneuverability make it a near-term competitor with other devices such as Hall thrusters. The subsequent extension to a p-B^{11} self-powered unit would address the demanding requirements for future high power space units. Much more research and development is required to ensure that steps occur in a timely fashion. However, due to the relatively small physical scale of the IEC, an aggressive experimental program can be undertaken at a reasonable cost."



One concept of an IEC fusion-powered spacecraft thruster. From (17).

The first phase of research and development will have the objective of designing, fabricating, and flying a small spacecraft in Low Earth Orbit to demonstrate an electric thruster that uses IEC fusion power in the space environment. Our goal is to launch the demonstrator within three years of the laboratory's founding.

The second phase of research will focus on maturing the technology to utilize a p-B^{11} power source for the thruster as a step toward future high thrust aneutronic fusion propulsion systems. Our long-term vision is development of aneutronic fusion propulsion that uses direct conversion to utilize the fusion reaction products to produce thrust at levels and efficiencies that will enable low-cost, rapid transport to the outer solar system and beyond. This represents the third and most challenging phase of research.

Aphelion Aerospace will provide engineering and launch services support to ARES Institute in executing the demonstration mission. Mr. Travis has committed to funding the launch using is shares of Aphelion Aerospace stock. This presents some risk as the value of the shares will vary and there is no guarantee at this time that the shares will be able to be monetized. The launch may be conducted by Aphelion Aerospace or a third-party launch provider. There is also the possibility of obtaining a launch funded by NASA, although probably unlikely given the agency's near-term priorities in the field of Fission Nuclear Thermal Propulsion.

Other Aerospace Investigations

Advanced propulsion research conducted by the laboratory could also include photokinetic plasma propulsion research. In tandem Florida Tech M.S. Theses in Physics, and Space Sciences (Richard F. Grant, 1990; Michael P. Moses, 1991, respectively), Dr. Edwin F. Strother (full Professor, then of the Physics Dept.) supervised the design, construction, and initial test firing of a unique Photocombustion Reactor, the Static Test Unit for a subsequent photokinetic plasma rocket thruster for satellite AKM, orbital positioning, and other, deep space, applications. An ISP in excess of 1816 seconds was calculated for the technology, at thrust levels commensurate with chemical systems. Though supported by industry contributions in the construction of the prototype, the diagnostic instrumentation required to effectively analyze the reactor firings was, at the time, prohibitively expensive. Today, flexible, inexpensive PC based supervisory control and data acquisition (SCADA) utilities have far greater capability and cost a fraction of what they did then, and portable spectroscopy equipment has likewise become readily available and affordable. In the interim, annual NASA, Air Force, and commercial funding for space propulsion research, with particular emphasis on electric, ion/plasma-based architectures has been increased by multiple orders of magnitude.

Next Generation Radiofrequency Antenna Architectures

Stealthy plasma antennas and plasma reflectors for radio communication and synthetic aperture radar applications are receiving significant support. When a plasma antenna is switched off, its electromagnetic signature effectively disappears; its nonconductive casing being nearly invisible to enemy radar. This thrust complements work previously done by the university in conformal antenna design for low observable applications (Thursby, et al). Researchers at the Australian National University and the University of Canberra have demonstrated plasma antennas with superior performance to metal ones, yet which also offer stealth as a bonus. In particular, they have demonstrated precise microwave beam reflection and steering by a plasma field, performing the same function as a parabolic dish.

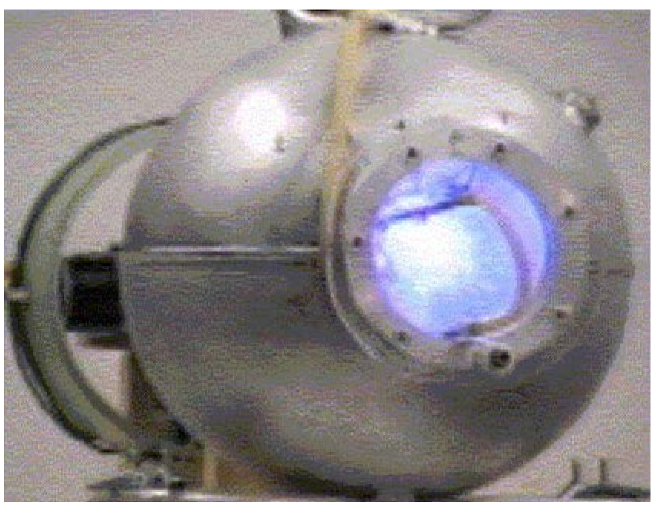
Australian National University Demonstration Transmitter

Australian National University Demonstration Receiver

Advanced Laser/Maser Systems Development

Research regarding the multimodal pumping of gas lasers (Caraway, et al) has indicated the potential for unique quantum gain when the lasing plasma is excited by different mechanisms and in different spectra simultaneously. Serendipitous observations of efficient CO dissociation in the lasing plasma are also of significant interest in their potential application to both monocrystalline carbon semiconductor fabrication and, more broadly, in the environmental remediation of industrial CO outputs. There is high risk/high reward funding available from industry on the former and from EPA and other sources on the latter.

The laboratory will extend the work toward practical application in a subsequent plasma device under more intensive instrumentation in the proposed lab, with data products specifically tailored to the proposal requirements of these funding sources.

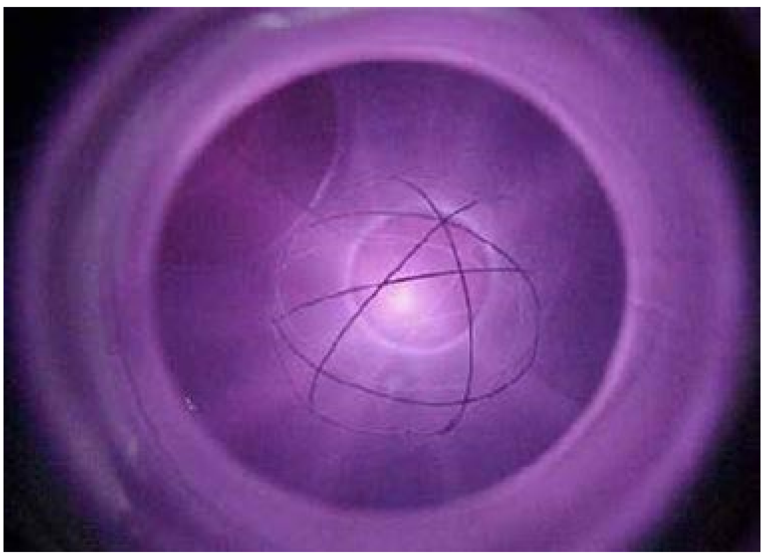


Resonant Cavity of Experimental High Yield Plasma Generator w/ Rotary Transformer Offering Self Induced Magnetic Cooling

Controlled Nuclear Fusion & Alternative Energy

The Farnsworth Fusor has been used to produce D+D, D+T, and D+3He fusion reactions since the 1950s, for scientific research and as a high intensity neutron source not requiring radioactive materials. Dozens of these small, lightweight, compact, simple, inexpensive reactors have been built, both by university researchers and hobbyists, over nearly half a century. Though it has yet to reach breakeven, Q > 0, all approaches to Inertial Electrostatic Confinement have not yet been exhausted, its future is promising, and the Fusor is less expensive to build (and operate) than a Tokamak by several orders of magnitude.

ARES Institute will propose a series of experiments with such a reactor, which do not appear to have been attempted or only with limited scope in an initial survey of the IEC literature: (1) The introduction of a photokinetic catalyst, introducing high energy chemical reaction transients likely to invoke oppositely ionized molecular collisions; (2) Mapping and manipulation of the auto-induced magnetic field of the plasmoid to enhance stability and apply compression by external field sources; (3) The use of adiabatic noble gas pneumatic compression of the magnetoplasmoid to leverage extreme forces on the plasma kernel; and (4) The application of focused acoustic standing waves and/or cavitation to the plasma field for supplemental heating, either prior to or following primary ignition.



Inertial Electrostatic Confinement of D+D Plasma Undergoing Fusion

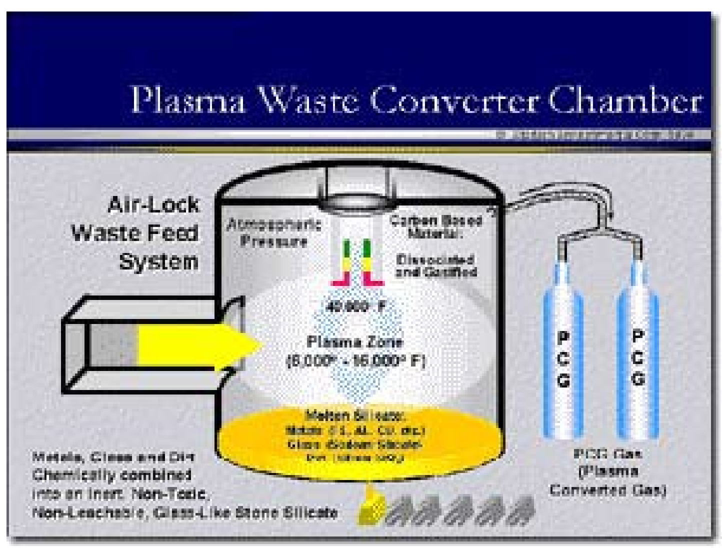
Mineral Refining, Materials Science & Industrial Processing

Recent work in semi-fuel cells using an Aluminum sacrificial anode and a saline/peroxide catholyte have indicated prospective energy storage density far superior to any other battery or fuel cell architecture, owing to the fact that each Aluminum atom surrenders three electrons when oxidized, vs. two for Zinc, Nickel, Lithium, etc. Research at Purdue (Rusek, et al) has demonstrated extremely high efficiencies for 97% peroxide catholytes with Aluminum, for high power space and naval applications, while others are developing slower discharge, aluminum/saline systems for waste recovery as electric power for the individual infantry soldier. In both contexts, a compact, high throughput mechanism for the reformation/reduction of the spent Al O analyte back into the metallic Aluminum fuel is considered a high priority enabling technology. Moreover, the Department of Energy has designated new approaches to Aluminum reduction as a critical technology need in its "Industries of the Future" program and is currently funding vapor phase reduction research. Precise electrodynamic control of an aluminum-oxide plasma could enable its reduction with far greater efficiency than the prevailing art. Any indications of progress on this key problem would be met with aggressive funding, both by the Department of Energy and the Aluminum industry, due to the economic leverage that more efficient processing would command in the marketplace. A related thrust in plasma vapor deposition of a high temperature Al O insulating foam (using a process developed at the University of Pennsylvania), represents a low cost, low maintenance alternative to Silicon Dioxide tiles for aerospace heat shielding applications. For various reasons, these investigations are symbiotic and synergistic, and both represent substantial funding prospects.

With an interdisciplinary background inclusive of Mechanical Engineering, and cognizant of industrial metal fabrication and processing issues in manufacturing, the laboratory could construct a benchtop plasma experiment system designed specifically for Al O investigations, with the versatility to pursue both lines of enquiry. In addition to the DoE IoF program, presentations would be made to the Aluminum Institute, and NASA to secure funding for advanced research using such a device.

Pollution Control, Waste Remediation & Resource Recovery

In the last 10 years, substantial progress has been made toward the efficient reformation of waste hydrocarbons to combustible liquid and gaseous fuels, using plasma technology instead of microbes. Three technology companies on Florida's Gulf Coast have individually each patented systems using plasmas to breakdown carbonaceous liquid wastes, such as sewage sludge, evolving a syngas with properties superior to LNG, Propane, or Acetylene for heating, power generation, and welding/cutting applications. The proponents each claim (with independent lab verification) that the safe, storable C/O/H/Trace Hydrocarbon fuel gas mixture bubbled up contains on the order of 2.77 times the energy content required to generate the underwater plasma which produces it. An evolving body of scientific evidence indicates a novel, previously unrecognized transient magnetic bonding phenomenon with respect to the Hydrogen escaping the plasma field, which has broader, profound implications for industrial chemistry. It is believed to resolve the longstanding anomalies surrounding the "Brown's Gas" controversy, of Australian physicist Dr. Yull Brown, which have never been otherwise satisfactorily explained.



FIRST YEAR EXPENSE PROJECTIONS

The table below shows the anticipated expenses during the first year of the laboratory operations. These figures are approximate and will likely change dependent on the level of funding we receive and further refining of the lab's startup plans.

The labor costs assume SPHERELAB will onboard a staff of 8 part-time (25-50% PTE) employees during the course of the year. Not all of the positions will be onboarded on day 1. Labor costs may be offset by utilization of student and intern resources and will be further refined based on the anticipated workload for each month of operations.

We plan to manage software licensing costs, which can be excessive, by taking advantage of the many startup programs offered by companies such as Autodesk, Siemens, AGI/ANSYS, Microsoft, and Amazon. We have utilized these programs in other organizations and found that they saved over 90% in fees compared to standard commercial licensing.

The other costs listed in the following table are approximations based on our prior experience and current plans for starting up the laboratory.

Labor	$ 242,460.00
Rent	$ 18,000.00
Utilities	$ 6,000.00
Office Equipment	$ 40,000.00
Laboratory Tools (inc. computing devices)	$ 50,000.00
Software Licensing	$ 75,000.00
G & A	$ 12,000.00
Consumables	$ 6,000.00
TOTAL	**$ 449,460.00**

The table below details the composition and labor cost for the initial engineering team during the first year of laboratory operations. The hours reflect the anticipated need and workload for each position. Those figures could, and likely will, change based on future project plans and schedules. A monthly breakdown of the hours and labor rate for each position over the course of the first 12 months can be provided upon request.

Functional Title	Hours	$ Total
Director	660	$43,230.00
Nuclear Engineer, Journeyman	570	$42,037.50
Aerospace Engineer, Senior	570	$52,725.00
Electronics & Instrumentation Engineer, Journeyman	320	$25,200.00
General Technician, Senior	110	$7,232.50
Model & Simulation Drafter, Junior	200	$9,500.00
Software Developer, Junior	190	$14,250.00
System Engineer, Junior	740	$48,285.00
TOTAL	**3360**	**$242,460.00**

ORGANIZATIONAL TEAM

LEAD ORGANIZATION: ARES INSTITUTE, INC.

ARES INSTITUTE

The **Aerospace Research & Engineering Systems Institute, Inc. (ARES Institute)** is a not-for-profit corporation operating in the state of Colorado (http://www.aresinstitute.org). ARES Institute is a 501 (c)(3) registered tax-exempt organization. ARES Institute develops innovative research programs involving academia, industry, and government organizations in order to benefit the aerospace workforce in the state. The primary purpose of the Institute is to engage students and university graduates at all levels in exciting aerospace-related projects and spur interest in math, science, and aerospace careers.

ARES Institute, Inc. is works to benefit the aerospace and engineering workforce of the future by developing and coordinating projects involving students at all levels, helping to inspire the younger generation to pursue science, math, and excellence.

Behind the programs of ARES Institute is the belief that one of the most effective means to make aerospace careers attractive to students is to engage them in hands-on endeavors and provide the experience and the excitement of accomplishing complex aerospace projects. This is essential during a time when universities are turning out fewer and fewer engineering graduates and even fewer are taking up careers in the aerospace industry.

ARES Institute works to create mutually beneficial partnerships among schools, private industry, and government. As a result, it is not only students who will benefit. Small businesses and aerospace corporations will benefit by being able to engage in research projects and create new products and technology for the commercial marketplace. The projects also serve as a form of recruitment for new employees in a manner similar to internship programs. Graduates are more likely to desire employment with firms they have worked with while still in school. A long-term benefit is developing, attracting, and keeping a skilled aerospace workforce, which will also help to enable the state to attract more high-tech and aerospace companies to locate in the state as opposed to other states.

COMMERCIALIZATION LEAD: IEC, INC.

Currently operating in stealth mode, **Interstellar Exploration Concepts (IEC, Inc.)** was incorporated in Colorado in 2022 with the mission to develop new enabling technologies for deep space exploration, in particular, Inertial Electrostatic Confinement fusion power and propulsion.

IEC, Inc. (http://www.iecfusion.com) will take the lead in commercializing technologies developed at SPHERELAB in partnership with ARES Institute, Aphelion Aerospace, and the support of a top-tier university collaboration. IEC, Inc. is focused more on the commercialization and promotion of new technologies to industry rather than the foundational research of those technologies, which is the purpose of ARES Institute.

UNIVERSITY COLLABORATOR: (TBD, UNIVERSITY OF ILLINOIS PREFERRED)

As explained throughout this paper, we believe that the ideal partner for this project is the University of Illinois. The Department of Nuclear, Plasma & Radiological Sciences at the University of Illinois, Urbana-Champaign has been a leader in the field of fusion research and possesses knowledge, experience, and infrastructure that would make collaboration more productive than with other universities. With its long history and deep experience, and being a world leader in IEC fusion research, the University of Illinois would be an ideal collaborator with the privately-owned research and development laboratory described in this paper. If such a relationship is established, it is our intent to locate SPHERELAB in Illinois, near the University campus, potentially at the University of Illinois Research Park.

VENDOR & SUPPLIER NETWORK

Aphelion Aerospace (https://aphelionaerospace.com) is a space transportation services company dedicated to developing responsive launch solutions and products for the nanosatellite industry. We aim to mass produce space vehicles through miniaturizing and vertically integrating dedicated, single-nanosatellite launch services. Our goals are to:

- Produce and fly a fleet of low cost, scalable nanosatellite launch vehicles.
- Produce and sell advanced small satellite (cubesat) components and systems.
- Produce and sell advanced in-space propulsion products derived from the launch vehicle
- Provide a regular, scheduled launch service, following a model similar to other terrestrial

transportation systems such as the airline industry.
- Create a complete, customizable, turnkey, nanosatellite solution with spacecraft components, software, and launch.

Aphelion Aerospace, Inc. is pursuing an innovative launch service business model that provides unprecedented cost-effectiveness, schedule certainty and mission flexibility to the customer. It features full price disclosure and services sold in a manner similar to airline ticketing. Regularly scheduled launches and one-month lead time to launch reduce lifecycle costs while customized orbits and on-demand launch capability fill a need that is not served by existing small launch vehicle.

Aphelion Aerospace will provide engineering and manufacturing support to SPHERELAB. In the future, Aphelion may provide launch services for the Phase 1 demonstrator mission or support launch with a third-party provider.

Aeropac, SA (http://www.aeropac.com.ar) has decades of experience in aerospace and launch system design, manufacturing, and operations. Aeropac will support SPHERELAB projects with their advanced simulation and analysis capabilities. Aeropac will also support our manufacturing and integration requirements.

Agreements with other vendors are pending finalization. These include vendors for software engineering, AI/ML, control center design and operation, and technical operations.

PUBLIC/PRIVATE PARTNER DESIRED CONTRIBUTIONS

To pursue the acquisition of funding to equip, support, and develop the proposed Plasma Technology Laboratory, the laboratory is soliciting support and contributions from external sources, including academic institutions, state/federal government opportunities, and philanthropic organizations. The support being sought includes the following:

- From our university partner, a Letter of Support from an appropriate official conveying support for SPHERELAB and intent to engage in future research collaboration.
- From our university partner, a Letter of Support from an appropriate official conveying interest in potentially working with the laboratory and its contractors in order to conduct an in-space demonstration of an IEC fusion-powered thruster on a small satellite.
- Access to a temporary workspace or surplus/deactivated laboratory for 90 days, at no cost or with deferred rent, such that preliminary on-site work can be conducted.
- Use of a load-carrying vehicle to collect and return to the laboratory necessary equipment such as near net shape components, high voltage transformers, fusor hardware, and other equipment acquired to establish the lab.
- Use of a conference room for meetings with faculty, presentations to industry

representatives (e.g., Northrop Grumman, OrbitFab, epsilon3, MicroAerospace Solutions and other prospective partners and investors), and potential government contracting officers from NASA, Space Force 45th Delta, AFRL/AFWERX, DARPA, and others.

- Proposal review and assistance to aggressively pursue grant opportunities, cover certain engineering work required for optimal proposals, and to support various requirements attendant to securing industrial cooperation and third-party collaboration for the lab.

ADDENDUM

While not incorporated into the body of this paper, it is important to note that there are additional opportunities for research grants and contract with NASA. Specifically, these include "Space Technology Research, Development, Demonstration, and Infusion (SpaceTech-REDDI), Space Tech Research Grants (NSTGRO), Early Stage Innovations (ESI), Space Technology Research Institutes (STRI), and Early Career Faculty (ECF) programs. Each of the aforementioned programs are administered by NASA's Space Technology Mission Directorate. Because these initiatives target university-led research rather than the private sector, SPHERELAB will not be eligible to be the lead organization. However, SPHERELAB will be able to enter into teaming agreements with a lead academic institution when there are appropriate opportunities under these programs. We intend to pursue such opportunities as they arise and fit with the research goals of SPHERELAB.

REFERENCES

1. “Space Probe Application of IEC Thrusters”, George H. Miley1, Hiromu Momota1, Linchun Wu1, Michael P. Reilly[1], Rodney Burton[2], Vince L. Teofilo[3], Dick Dell[4], Richard Dell[4], and William A. Hargus[5]
    1. Dept. of Nuclear, Plasma and Radiological Engineering, University of Illinois,
    2. Dept. of Aerospace Engineering, University of Illinois
    3. Lockheed Martin Space Systems Co., Advanced Technology Center
    4. Advanced Aerospace Resource Center (AARC)
    5. Air Force Research Laboratory, Edwards AFB
2. "Inertial-Electrostatic-Fusion Propulsion Spectrum: Air-Breathing to Interstellar Flight", by Robert W. Bussard and Lorin W. Jameson, Energy/Matter Conversion Corporation
3. "Inertial Electrostatic Confinement (IEC) Fusion: Fundamentals and Applications", George H. Miley .and S. Krupakar Murali, 2014.
4. "Spacecraft Applications for Aneutronic Fusion and Direct Energy Conversion", John Scott, Project Lead, NASA/JSC-Energy Conversion Systems Branch, Jeff George, NASA/JSC-Energy Conversion Systems Branch, Paul March, Engineering Support Contract Group/Houston, George Miley, Ph.D., University of Illinois, Urbana-Champaign/Dept. of Nuclear, Plasma, and Radiological Engineering, Alfonso Tarditi, Ph.D., Electric Power Research Institute/Knoxville-Houston, H. "Sonny" White, Ph.D., NASA/JSC- Propulsion Systems Branch, 2012, NASA JSC
5. "Some Interplanetary Missions Using IEC Fusion Propulsion", John M. Hanson, Vehicle Flight Mechanics Group, NASA MSFC, 2001 NASA.
6. "Inertial Electrostatic Confinement (IEC) Fusion: Physics and Applications", Dr. George H. Miley, University of Illinois, NPL Associates Inc., 2011.
7. "Research Status of IEC Experiments at NASA Marshall", Chris Dobson, NASA MSFC, Ivana Hrbud, ERC, Inc., 2002 NASA MSFC.
8. "Inertial-Electrostatic Confinement (IEC) Fusion for Space Propulsion", Jon Nadler, Ph.D., Richland Community College, University of Illinois, University of Alabama, 1999, NASA MSFC.
9. "Aneutronic Fusion Spacecraft Architecture", NASA-NIAC 2001 Phase I Research Grant Final Research Activity Report, P.I.: Alfonso G. Tarditi, Dept. of Physics, University of Houston, John H. Scott, NASA Johnson Space Center, George H. Miley, University of Illinois Urbana-Champaign, 2012, University of Houston.
10. "Fusion as Electric Propulsion", Robert W. Bussard, Pacific-Sierra Research Corporation, 1988, Pacific-Sierra Research Corporation, AIAA
11. "From SSTO to Saturn’s Moons: Superperformance Fusion Propulsion for Practical Spaceflight", Robert W. Bussard and Lorin W. Jameson, Energy/Matter Conversion Corporation, 1994, , Energy/Matter Conversion Corporation.
12. "Aneutronic Fusion Propulsion for Earth-to-Orbit and Beyond", H.D. Froning, Jr.,Flight Unlimited, Robert W. Bussard, Energy/Matter Conversion Corporation, 1998, Space Technology and Applications International Forum.
13. "Fusion Ship II - A Fast Manned Interplanetary Space Vehicle Using Inertial Electrostatic Fusion", J. Webber, R.L. Burton, H. Momota, N. Richardson, Y. Shaban, and G. H. Miley, 2002, NPL Associates, University of Illinois.

14. "The QED Engine System: Direct-Electric Fusion-Powered Rocket Propulsion Systems", Robert W. Bussard Energy/Matter Conversion Corporation, 1993, American Institute of Physics.
15. "System Technical and Economic Features Of QED-Engine-Driven Space Transportation", Robert W. Bussard, Energy I Matter Conversion Corp., 1997, American Institute of Aeronautics and Astronautics, Inc.
16. "The Need For Fusion Propulsion Research", R. Adams, NASA Marshall Space Flight Center and J. T. Cassibry University of Alabama in Huntsville (UAH), Propulsion Research Center, 2005.
17. "Inertial Electrostatic Confinement: Innovation for Electric Propulsion and Plasma Systems", Yung-An Chan Research Associate, Institute of Space Systems (IRS), University of Stuttgart and Georg Herdrich, Priv.-Doz., Head Plasma Wind Tunnels and Electric Propulsion, IRS, University of Stuttgart, 2017, 35th International Electric Propulsion Conference.
18. "Aneutronic Fusion Propulsion", Defense Intelligence Reference Document, 2010, Defense Futures.
19. "Breakthrough Propulsion Study Assessing Interstellar Flight Challenges and Prospects", Marc G. Millis, Jeff Greason, Rhonda Stevenson, Tau Zero Foundation, NASA Grant No. NNX17AE81G First Year Report, 2018, Tau Zero Foundation
20. M. Tekant, "Magnetic Fusion Machines," Physics 241, Stanford University, Physics 241, Winter 2013.
21. R. Islam, "Inertial Confinement Fusion: A Promising Alternative?" Physics 241, Stanford University, Winter 2015.
22. W. C. Elmore, J. L.Tuck, K. M. Watson, "On the Inertial-Electrostatic Confinement of a Plasma," Phys. Fluids 2, 239 (1959).

"It is difficult to say what is impossible,
for the dream of yesterday is the hope of today and the reality of tomorrow."
~ Dr. Robert H. Goddard, Father of Liquid Rocketry