Princeton Satellite Systems, Inc.

Fusion Engines for Satellites and Beyond

Notable Investor

Tejpaul Bhatia Past

CRO @Axiom Space

Customers

Discovery Discovery Discovery

$0 RAISED USD

0% of minimum target: $100,000

0% of maximum goal raised: $1,235,000

0 Investors

$150 min for US investors.

Highlights
Summary
Media Mentions
Deal Terms
Problem
Solution
Product
Traction
Customers
Business model
Market
Competition
Team
Vision
Use of Funds
Company
Risks & Disclosures
Documents

HIGHLIGHTS

NASA NIAC funding

Created thrust and system model of Direct Fusion Drive

3 DOE INFUSE Awards, 2022

Created thrust and system model of Direct Fusion Drive

Intellectual Property

Six granted PFRC (product) patents;1 owned & 5 licensed

SUMMARY

PROBLEM Power and propulsion limitations of current rocket engines inhibit interplanetary travel

SOLUTION Fusion propulsion and power in one device will transform deep space missions with half the trip time, 10x the payload and 200x the available power.

PRODUCT PFRC - a compact, linear fusion reactor that doubles as a fusion rocket for space applications.

TRACTION $600K+ in Innovation Network for Fusion Energy (INFUSE) funding in 2022, LOIs from DoD organization for nuclear fusion propulsion , $1M government contract for state-of-the-art power electronics for fusion systems , 2016 & 2017 Phase I & II NASA NIACs awards for Fusion-Enabled Pluto Orbiter and Lander

CUSTOMERS DoD, NASA, FEMA

BUSINESS MODEL Transactional

MARKET Approx. Market Size: $30B

COMPETITION No other fusion companies are focused on producing specific impulse and power for rapid deep space transportation.

TEAM A team with decades of government and commercial development experience.

VISION A bold, inspiring world of space exploration enabled by DRD/PFRC technology

USE OF FUNDS Match federal INFUSE investment and gather critical data from the PFRC experiment for designing the next-generation superconducting machine.

MEDIA MENTIONS

The Space Show Broadcast
The Space Show

Have Fusion, Will Travel
ITER

DEAL TERMS

How it works

Deal type	Convertible debt
Valuation cap	$12,000,000.00 USD
Discount	20.0%
Maturity date	April 30, 2026
Type of security	Convertible debt
Interest rate	5.0%
Investment range	$150-$100,000 USD
Funding goal	$100,000-$1,235,000 USD

Closing date	April 30, 2023, 2:00 AM ET
Carry	0%
Investor Fees	$0

PROBLEM

Power and propulsion limitations of current rocket engines inhibit interplanetary travel

Today's deep space missions are too slow and expensive to enable the kind of interplanetary travel imagined by science-fiction and aspirational NASA roadmaps. The few experiments selected to go to space must make tough compromises in cargo mass – "payload" – and power, with harsh limitations on capability and data return. Once launch day comes, scientists must wait many years while their spacecraft executes complicated trajectories looping around the solar system for gravity assists. These long trip times drive up costs.

Interplanetary transit times using conventional chemical propulsion are 9 months to Mars, 5 years to Jupiter [1], and 7 years to Mercury [2]. Such prolonged timeframes mean large radiation doses; dangerous for humans and damaging to spacecraft components. Maintaining skilled staff and monitoring spacecraft during transit is also expensive. Many experienced scientists may even retire before their instruments reach their intended orbit.

With current propulsion systems, launches have to be timed just right and take place within a "launch window"; The launch window for cheapest (lowest fuel) travel to Mars only occurs every 26 months [3]. This means that, if the window is missed, for whatever reason, we have to wait more than two years for another opportunity to launch again. Revolutionary improvements in space propulsion are needed to make interplanetary travel fast and economical.

What are the options for better propulsive performance?
To answer this question, we must first understand how propulsion works.

All propulsion systems need a source of energy and a means of converting that energy into a directed flow (exhaust) that produces thrust. The faster you can make the exhaust come out of an engine, i.e. high "exhaust velocity," the less fuel you need. The more thrust you generate, the more cargo you can move, and the faster you can accelerate. It's an inexact analogy, but you can compare types of rockets to transportation on Earth: if you go on vacation in your car, you can bring all the gear and luggage you want. If you fly, it's much faster but more expensive and you can only bring a suitcase or two. In essence, you can trade luggage and cost for time, as we can trade payload capacity for time, when comparing different propulsion systems characterized by different combinations of velocity and thrust.

Our best propulsion options today are chemical propulsion (usually mixing two fuels) and electric propulsion (energizing heavy ions). Chemical propulsion systems have high thrust but very low exhaust velocity (3 km/s) and hence limited deep space capability [4]. Solar-powered electric propulsion systems with their higher velocity – up to 45 km/s [5] – can move payloads with less fuel, but typically only slowly, because in order to get high thrust you need a lot of power. NASA [6] and DARPA [7] are investing in nuclear thermal propulsion (NTP) for better performance, where the fission (splitting of atoms) of low-enriched uranium is used to heat engine fuel producing high thrust and somewhat faster fuel (9 km/s), but the development of NTP is still early-stage and anticipated improvements in trip times are modest [8]. None of these engine types can produce both substantial thrust and high fuel velocity – what would be needed to bring your whole car full of gear for a trip, and get there as fast as an airplane would.

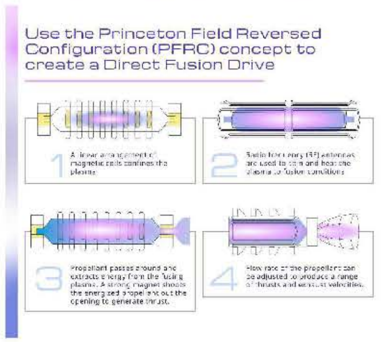
High power for electric propulsion; needed to enable faster trip times, could come from either fission or fusion reactors, however, the power source must also be lightweight, and fission reactors are not. Recent advancements in computation and materials, especially superconductors and semiconductors, have caused a resurgence of interest and progress in various fusion concepts. There are now multiple commercial fusion companies competing to be the first to put electricity derived from nuclear fusion on the grid. However, most fusion systems attempting to do this must be large due to their fundamental physics. To produce 200 MW or more, they would need to be as big as a building, and still have no means of producing propulsive thrust. If the fusion energy produced by these systems has to be converted into electricity before it can be used to generate thrust, it will suffer from the same limitations as electricity derived from nuclear fission – a big increase in system mass. In contrast, a direct drive fusion system – where the fusion energy is directly converted to rocket thrust without any intermediate steps – could reduce the total mass per unit of power by an order of magnitude or more, enabling rapid trip times while greatly reducing fuel requirements.

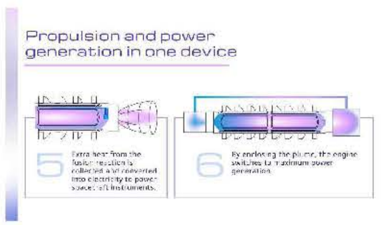
SOLUTION

Fusion propulsion and power in one device will transform deep space missions with half the trip time, 10x the payload and 200x the available power.

Fusion is the same process that powers our sun. Combining two smaller atoms to make a bigger one releases tremendous energy. If this energy can be converted into thrust, fusion propulsion technology will create a revolutionary shift in space travel, allowing for the expansion of humankind's presence in the solar system and beyond [9].

Fusion reactors use either deuterium and tritium (D-T) or advanced fuels such as deuterium helium-3 (D-3He) or hydrogen and boron-11 (H-11B) as reactants. Reactors that use D-T usually only produce electric power and must be coupled with a separate propulsion system to create thrust, losing efficiency and adding mass. Fusion involving advanced fuels produces charged atomic nuclei that can be directed with electromagnetic fields, producing thrust without an intermediate stage and dramatically reducing the mass needed for the reaction. For the D-3He fusion reaction, the ions produced have velocities of 25,000 km/s. This is about right for missions to our neighboring star Alpha-Centauri, but for interplanetary missions, it is necessary to mix more traditional fuel with the fusion products to get exhaust velocities in useful ranges (between 80 and 200 km/s.)





Of the current fusion propulsion technology concepts in commercial development, only the Princeton Field-Reversed Configuration (PFRC) is small and light enough to fit on today's launch vehicles. PFRC is an advanced fuel reactor that can mix propellant to produce thrust directly. The PFRC works by passing a cool plasma (a partially-ionized gas that contains ions, electrons, and neutral atoms), typically hydrogen, along the fusion region of the PFRC to collect the energy created from the fusion products (charged ions). By allowing this energy to escape as a plasma plume, PFRC can effectively become a fusion rocket called the Direct Fusion Drive (DFD). By changing the flow rate in the cooling layer, DFD can produce a range of thrusts and specific impulses (a measure of how efficiently a reaction mass engine creates thrust) for a given power level. The DFD will allow deep space missions to fly directly to their destination rather than having to use complex gravity assists from other planets.

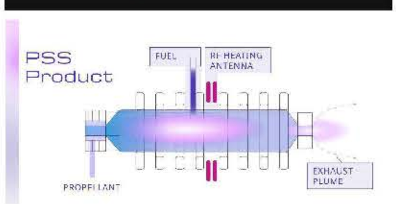
Reducing trip times and increasing payload is of critical importance, but having large quantities of power upon arrival at the deep space destination is itself transformative: power to drill, power to use lasers to beam back vast quantities of data, power to support people. Conventional generators used as a power source (like the one used on the Mars Perseverance rover [10] and the Pluto New Horizons mission [11]) produce only a few hundred watts, and a single image might take days to transmit from the outer planets back to Earth. A PFRC engine can produce tens or hundreds of kilowatts of power even while in propulsive mode (thruster), and a megawatt in reactor mode (power generator). Put simply, the PFRC provides power and propulsion in one device.

Missions enabled by the DFD include short-trip conjunction (~540 days on Mars, shorter time in space) and opposition-class (~30 Days on Mars, longer time in space) Mars missions, rapid inner and outer planet missions, asteroid and comet interception for planetary defense, asteroid mining, and near-interstellar missions including using the sun's gravitational effect on light to observe exoplanets (planets not in our solar system) [12].

DFD can reduce trip times and enable increases in mission payload size when compared with conventional technology in all cases. This can greatly enhance and improve the scientific and commercial return of missions. In addition, PFRC space reactors can safely power large space stations and manned lunar and Mars bases. There is no doubt that using Princeton Field-Reversed Configuration (PFRC) technology in a Direct Fusion Drive (DFD) which can produce both power and thrust will help humanity explore our solar system.

PRODUCT

PFRC - a compact, linear fusion reactor that doubles as a fusion rocket for space applications.



PFRC - a compact, linear fusion reactor that doubles as a fusion rocket for space applications.

The Princeton Field-Reversed Configuration (PFRC) concept leads to a 1 to 10 MW fusion microreactor. The deuterium and helium-3 fuels used as PFRC reactants are safe and nonradioactive. DFD rockets will achieve 5 to 10 N per MW of fusion power with a specific impulse of 8,000 to 20,000 seconds while producing tens to hundreds of kilowatts of additional electricity. PFRCs would be built in a factory and shipped, fully fueled for their 30-year operational lifetime, to the customer.

Princeton Satellite Systems' development roadmap focuses primarily on the potential space and military markets for small fusion reactors. Expected public private partnerships will help fund this development.

There are three key aspects of the PFRC technology that enable a compact fusion rocket [13]:

Single RF Heating System. This innovative, odd-parity system creates rotating electric and magnetic fields that drive currents in the plasma. A Field Reverse Configuration (FRC) has a magnetic null, where the current drive is most efficient. Radiofrequency (RF) heating pushes the ions in cycles, causing explosive heating. The high beta FRC configuration means that only modest magnetic fields are needed to confine the RF-heated plasma - magnets about the size of an MRI machine.

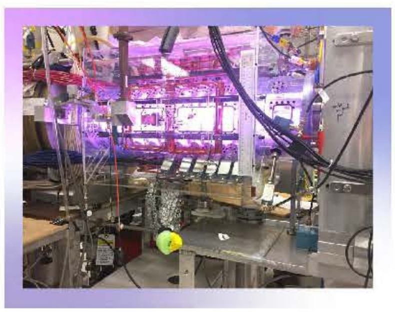
Advanced Fuels. The PFRC configuration has an intrinsic fusion exhaust mechanism: the fusion products transfer their energy to the propellant flowing around the fusion region. This process is intimately connected to the size of the reactor and only occurs if the machine is small. Coupled with the high efficiency of the FRC configuration, the PFRC can burn advanced fusion fuel while exhausting the dangerous ash, resulting in negligible neutron radiation. This in turn means that only minimal radiation shielding is required - the crucial feature which keeps the reactor mass down and the specific power up. Without advanced fuels, the shielding mass would dwarf the rest of the engine and the reactor would be too heavy to operate as a rocket.

Natural Thrust. The PFRC is an FRC inside a mirror, which has a natural linear form. For closed-loop power production, both ends are closed and the cooling plasma is recycled. With one end open, the mirror creates a fusion rocket. Energy which was transferred to the electrons in the propellant is converted to ion velocity in the magnetic nozzle, creating thrust. The ion velocity is about 100 km/s, which is a specific impulse of about 10,000 sec. The PFRC can uniquely produce electricity at the same time by recycling the energy absorbed by the walls of the reactor.

We have a staged development plan to achieve fusion in the PFRC.

PFRC-1 first demonstrated our unique heating method, RMFo, in 2007. RMFo stands for odd-parity rotating magnetic fields, where a set of antennas driven with oscillating signals drive plasma current. In RMFo, this special antenna configuration creates the FRC plasma formation with closed field lines, crucial for lengthening the plasma's confinement time.

PFRC-2, with twice the radius, began operations in 2011. PFRC-2 uses passive high-temperature superconducting flux conservers to confine the plasma. The magnetic field is provided by water-cooled copper magnets, so the PFRC-2 is limited to a field of about 0.05 T, where T stands for magnetic field strength or flux density.



The PFRC-2 Experiment at the Princeton Plasma Physics Lab. The RMFo antenna are the orange, Kapton-tape wrapped rectangles.

PFRC-3 must have a magnetic field of about 1 T, which requires a fully-superconducting array of magnets. If PFRC-3 is successful, a PFRC-4 with a field of about 5 T would be able to achieve a breakeven fusion of deuterium and helium-3. We could then build a flight prototype of a true fusion rocket, the Direct Fusion Drive, followed by its first mission in space.

In addition to being a compact fusion rocket, PFRC will also make a compact terrestrial fusion reactor. This reactor could be used in modular and distributed power plants, in portable systems like ships or mobile emergency generators, and in remote off-grid locations.

TRACTION

$600K+ in Innovation Network for Fusion Energy (INFUSE) funding in 2022

LOIs from DoD organization for nuclear fusion propulsion

$1M government contract for state-of-the-art power electronics for fusion systems

2016 & 2017 Phase I & II NASA NIACs awards for Fusion-Enabled Pluto Orbiter and Lander

Our NASA NIAC grant (2016-2018) allowed us to perform a systematic analysis of how DFD will work and how big all the subsystems will be, giving us confidence that if a fusion gain of about 3 can be achieved, the rocket will operate as intended.

More recently, PSS was selected for three awards by the Department Of Energy (DOE) Innovation Network for Fusion Energy (INFUSE), which funds national lab or university support for commercial fusion projects and requires the commercial

company to contribute to this effort in the form of "cost share":
Antenna Optimization: Simulating RF antenna designs for PFRC plasma heating and sustainment – $300K federal, $75K cost share/PSS
PFRC Stabilization: Stabilizing PFRC plasmas against macroscopic low-frequency modes – $240K federal, $60K PSS
Electron Profiles: Measuring electron density profiles on PFRC with USPR – $62K federal, $57K PSS

These awards are for simulations and for new antenna arrangements to increase the efficiency of the PFRC's unique heating method, which will enable the team to test antennas in multiple software products. The PFRC Stabilization project will allow us to simulate PFRC plasmas on supercomputing clusters using GPUs at fantastically small time scales. The third project is experimental and will bring a diagnostic from UC Davis, previously paid for by the Advanced Research Projects Agency – Energy (ARPA-E), to the PFRC to measure electron density across the plasma. Overall, this is a 3:1 match of federal grants to private dollars.

In recognition of the rapidly changing fusion technology landscape, NASA, DARPA and the DOE hosted a TriAgency workshop on Compact Fusion in April 2021 [14]. The consensus was that compact fusion is an important strategic technology and is deserving of funding, as shown by these quotes:

NASA's Ron Litchford, Principal Technologist for Propulsion: "Compact fusion stands as a well deserving candidate for an aggressive whole-of-government R&D initiative."

DARPA: "Compact fusion represents an emerging strategic technology with future potential Department of Defense (DoD) applications."

ARPA-E's Scott Hsu: "There's already very broad stakeholder interest in compact fusion and its space and defense applications. Fusion space propulsion is possibly the lowest hanging fruit in terms of a first application for compact fusion."

Government programs from NASA to DOE to DoD are taking notice of the progress in commercial fusion and creating competitive opportunities. NASA's recent release of a fusion propulsion topic for their Early Stage Innovations program for universities is a perfect example of this [15]. NASA wants its researchers to be able to run experiments on compact fusion devices to corroborate their models, and both PFRC-2 and the planned PFRC-3 could meet this need.

We recently proposed a Defense Innovation Unit program in nuclear propulsion. While we were not selected for an award due to the long-term development plan, our proposal was rated highly and we received a letter of support:

"PFRC was recently evaluated by the Defense Innovation Unit (DIU) for their Area of Interest, Nuclear Advanced Propulsion, and Power (NAPP). PFS' proposal received high marks from all reviewers. Due to the development time frame of ten to fifteen years, it was not within DIU's charter to deliver technology to the warfighter in three to five years.

DIU was impressed by how compact and powerful the PFRC can be without requiring any exotic technology or materials due to its low radioactivity... The first great power to exploit fusion propulsion effectively for maneuver could have a significant advantage in sustaining space superiority if not supremacy. A Fusion propulsion system would far out-compete nuclear thermal and nuclear electric propulsion on a power density and delta-V capability basis while offering restart and significant payload electrical power capability. Research and development efforts like PFRC are critical to raising the TRL of promising space technologies."

PSS has an ongoing $1M contract with ARPA-E to develop wide bandgap amplifiers for fusion systems needed for plasma heating and control systems. In a project with United Silicon Carbide (now Qorvo), we created a new cascode amplifier with a 15% higher voltage rating and 18% lower resistance. PSS and Princeton University are designing three types of boards using these devices: short high power pulses (~ 5 µs), control pulses (~ 1ms), and RF amplifiers (10's of MHz). The microsecond pulse waveform can be used for pulsed fusion systems such as z-pinches, merging FRCs, and inertial confinement fusion. The millisecond pulse waveform can be applied to active magnetic control of steady-state fusion reactors such as tokamaks, stellarators, and FRCs. The RF waveform is applicable to a key plasma heating technique, ion cyclotron resonance heating (ICRH), in these steady-state fusion reactors.

CUSTOMERS

DoD
DISCOVERY

NASA
DISCOVERY

FEMA
DISCOVERY

The Department of Defense (DoD) is the largest potential customer for the first PFRC production units. Military customers require high survivability and ease of operation, and cost per watt is not a driving factor. For example, military uses are for bases and installations, of which there are over 1000 worldwide; forward teams in the Army and Marines, surface ships, submarines, drones and space vehicles. The military industry wants to move to an all-electric battlefield where brigades can operate for a week without resupply. Diesel supply lines and storage facilities are attractive targets for enemy forces, an issue called contested logistics. PFRC meets the DoD's power needs safely and securely.

The National Aeronautics and Space Administration (NASA) is a key potential customer for both deep and near space missions where high power is enabling. This includes lunar and Mars surface power, Mars transportation, and deep space missions to Jupiter and beyond. Mars trips that will take 8 to 9 months with chemical propulsion can be cut in half, increasing astronaut safety and reducing cost. Robotic missions that have been limited to a few hundred watts with a single image taking days to transmit home, will be able to power drills and return high-definition TV. Human exploration, space resource utilization, and the search for life will all be fundamentally altered.

Civilian customers include emergency responders like the Federal Emergency Management Agency (FEMA) and remote locations where traditional electricity costs are high. This encompasses applications like mining at high latitudes, where solar and wind power are not effective and fossil fuels are expensive to transport.

BUSINESS MODEL

Transactional
A one-time sale of goods or services

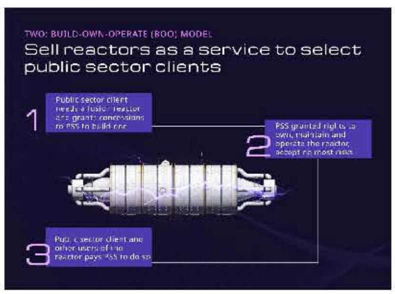
PFRCs are small enough to be built in a factory and shipped, fully fueled, to the customer. We expect to build and operate this process in-house. Fusion reactor market penetration will benefit from a build-own-operate (BOO) service. If the company builds, fuels, operates and decommissions the plant, it greatly reduces the burden on the receiving party. This is much easier with reactors as small as PFRC.

A DFD engine can be launched into space on a single rocket with all the fuel and propellant needed for the mission – no complicated in-space operations will be needed. PFRCs can be used for power on the moon, on Mars, or on manned space stations. We will actively seek to partner with a prime aerospace company like Northrop Grumman to build and test space reactors and rockets. A space version of the reactor would likely be a hundred times more expensive than a terrestrial unit.

The first product will be a 1 MWe portable power unit such as the one shown here.

A unit designed for space will require additional development time, estimated at 5 years. This is necessary to establish the robustness of all the components for a truly hands-off operation, and to flight-qualify specific items like the radiators and heat engine. A 1 MWe unit with the same magnet design as the first terrestrial portable product will be applicable to many near-term missions, from robotic deep space missions to surface power on the moon and Mars.

After the 1 MWe unit is successfully deployed, we will develop a commercial 10 MWe design. This will be applicable to modular power plants and a distributed power grid. A larger reactor will have some economies of scale for the large mirror magnets and will be less than 10 times as expensive as the 1 MWe unit.



MARKET

$30B
Approximate Total Market Size

The graphic shows the near-term portable power market in the US alone, including space. There is an immediate market for 30 units per year. This market is not sensitive to the levelized cost of electricity (LCOE). Military customers include bases, which number in the thousands, forward combat teams and ships. The ships market would initially be small submarines, both autonomous and for carrying special operations command teams. Forward teams are currently dependent on diesel and gas power supplies, which are vulnerable to attack.

The space market segment is smaller in number, with perhaps 4 launches a year for both DoD and NASA missions, but the reactors will be commensurately more expensive.

Current estimates of LCOE of $0.16/kWh would make the PFRC an attractive power source in some U.S. markets and places like Singapore. Alaska is an example of a domestic power market with very high costs of electricity, where towns would benefit from a standalone, firm power source like PFRC. Dozens of towns would be candidates for PFRC microgrids. Other isolated areas with high costs or areas with damaged power grids include Hawaii and Puerto Rico.

COMPETITION

No other fusion companies are focused on producing specific impulse and power for rapid deep space transportation.

Power options in deep space are currently limited to those from solar or radioisotopes. Solar power drops with the square of the distance from the sun so that panels producing 1000 W at Earth make only 40 W at Jupiter. Deploying very large and highly efficient solar arrays are quite expensive and introduce operational issues because of their flexibility. Radioisotope generators are heavy, expensive and further limited to producing a few hundred watts. NASA is working to develop fission power systems in the 1 to 10 kW level, but they will also be expensive and require launching radioactive materials. Fusion systems increase the scale of available power by a factor of tens of thousands compared to the current state-of-the-art.

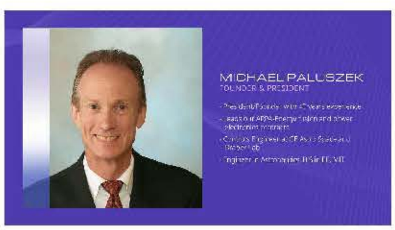
Amongst fusion systems, our DFD stands alone in its capabilities. TAE is a commercial fusion company with about $1B in investment. They are designing a large beam-fueled FRC to burn proton-boron 11 fuel. They have announced reaching 5 keV "total temperature," however,their reactor must be large for the beam-heating to be absorbed by the plasma, which precludes its use in space.

Helion is another commercial fusion company with a valuation greater than $1B. They are developing a pulsed FRC with heating via merge and compress. They intend to burn helium-3 and deuterium. They have announced reaching 9 keV "bulk plasma temperature," however their FRCs merge in the center of the machine and do not have any thrust mechanism. Their target power level is also 50 MW, which is too high for near-term space missions.

Both TAE and Helion are developing FRCs for use with advanced fuels, with good results for confinement. This research applies to our FRC confinement as well, even though the heating mechanisms are different. FRCs can burn advanced fuels due to their high beta, which is the ratio of the plasma pressure to the magnetic pressure; they can achieve higher temperatures and densities even with lower magnetic fields.

TEAM

A team with decades of government and commercial development experience.



Mr. Michael Paluszek
Founder and President
Mr. Paluszek has forty-one years of experience in nuclear fusion power systems, software design, Artificial Intelligence, control system design, analysis, and simulation of aerospace and energy systems. He is the PI on our ARPA-E OPEN and GAMOW programs on fusion reactors and fusion power electronics. Prior to founding PSS in 1992, Mr. Paluszek was an engineer at General Electric (GE) Astro Space in East Windsor, NJ and at Draper Laboratory, where he worked on the Space Shuttle, Space Station, and submarine navigation. He has a Bachelor's in Electrical Engineering (1976) and an Engineer's degree in Aeronautics and Astronautics (1979) from the Massachusetts Institute of Technology.

- President/Founder with 40 years experience
- Leads our ARPA-E fusion and power electronics contracts
- Controls engineer at GE Astro Space and Draper Lab
- Engineer in Astronautics, B.S in EE, MIT

Ms. Stephanie Thomas
Vice President and DFD lead
Ms. Thomas has been at PSS since completing her SB (1999) and SM (2001) in Aeronautics and Astronautics from the Massachusetts Institute of Technology. She is a NASA NIAC fellow for the study, "Fusion-Enabled Pluto Orbiter and Lander", led our NASA STTR on superconducting magnets for space fusion systems, and has led projects on rendezvous and proximity operations, defensive counter space, autonomous planning, and solar sails. She is the Vice Chair of the AIAA Nuclear and Future Flight technical committee and a member of the Fusion Industry Association's space committee. She is co-author of several books, including "MATLAB Recipes" (2015) and "MATLAB Machine Learning," (2017) published by Apress. While a graduate student at MIT, Ms. Thomas worked on modeling spacecraft electric propulsion and plume impingement of Hall thrusters.

- VP/Co-owner with 20 years experience
- Leads our fusion rocket contracts
- Leads commercial software product development
- Masters & B.S. in Astronautics, MIT

Dr. Christopher Galea
Research Scientist
Dr. Galea joined PSS after completing his Ph.D. in Mechanical and Aerospace Engineering at Princeton University in 2021 (S.B. Aerospace Engineering and Physics, Massachusetts Institute of Technology, 2016.). He has expertise in plasma diagnostics, short-pulsed lasers, and plasma physics. In his graduate research, he investigated the implementation of a laser- and microwave-based diagnostic technique, Radar REMPI (Resonance-Enhanced Multi-Photon Ionization), in novel environments relevant to plasma propulsion and remote sensing applications. At PSS, he has been running the x-ray energy diagnostic on the PFRC-2 and working on aerospace technology development, fusion power electronics, and plasma-circuit models.

- Lead Research Scientist
- Laser, microwave, and x-ray plasma diagnostics
- Ph.D. in Mechanical/Aerospace, Princeton
- B.S. Astronautics and Physics, MIT

Dr. Sangeeta Vinoth
Research Scientist
Dr. Vinoth is a part-time researcher at both Princeton Plasma Physics Laboratory and Princeton Satellite Systems. She has expertise in plasma spectroscopic diagnostics and computational modeling. She works on the x-ray and spectroscopy diagnostics on the PFRC-2 and power electronics for plasma heating and control, and analysis of radiation on the components. She has a Bachelor's degree in Physics (2002), a Master's degree in Nuclear Physics (2004), and a Ph.D. in Plasma Physics (2012), from Mumbai University, India. In her graduate research, she performed a comparative study of an ICP Inductively Coupled Plasma reactor flow models and operating conditions.

- Research Scientist
- Spectroscopy and x-ray plasma diagnostics
- Ph.D. in Plasma Physics, U. Mumbai

Advisory Board

Dr. Sam Cohen
PPPL advisor, inventor of PFRC
Dr. Cohen is a principal physicist at the Princeton Plasma Physics Laboratory with over 40 years of experience and a Ph.D. from MIT. He invented the odd-parity heated PFRC and supervises the PFRC-2 experiment. His research interests include the physics of field-reversed configuration plasmas with emphasis on fusion issues, aneutronic fuels, confinement, heating, non-linear dynamics, stability, and advanced plasma thrusters for propulsion of spacecraft to remote planets and beyond.

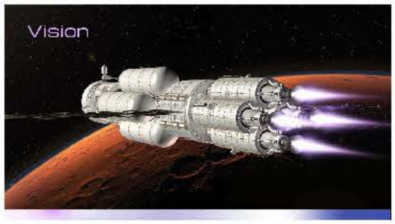
Dr. John G. Cramer
Dr. John G. Cramer is Emeritus Professor of Physics at the University of Washington in Seattle. His research interests include quantum optics, nuclear, and ultra-relativistic heavy ion physics with over 300 peer-reviewed publications. John has served on Program Advisory Committees for multiple large experiments including the 88" Cyclotron (Lawrence Berkeley National Lab). He presently serves as Chair of the External Council of the NIAC innovative-projects program of NASA. John is a prolific author whose works include The Quantum Handshake - Entanglement, Nonlocality, and Transactions (Springer 2016), the science fiction novels Twistor, Einstein's Bridge, and Fermi's Question, and over 200 popular-level "The Alternate View" science columns published bimonthly (1984 to present) in Analog Science Fiction and Fact Magazine.

Founding Story
Princeton Satellite Systems began in 1992 as a consulting company providing launch support services to several communication satellite launches, including Cakrawarta/Indostar I, Koreasat, AsiaSat and Echostar. Once we developed our commercial aircraft and spacecraft control toolboxes, we began offering training and MATLAB consulting, helping our customers derive the maximum utility from their purchase.

The company's commercial software is used worldwide for engineering design. Our advanced research for agencies like NASA and the Air Force keeps PSS's software on the cutting-edge. Our research has resulted in the award of seven patents, ranging from optical sensors to proximity spacecraft maneuvering to target tracking to fusion propulsion. We have collaborated with Princeton Plasma Physics Laboratory on fusion propulsion since 1998 and first presented the Direct Fusion Drive at the Defense Advanced Research Projects Agency 100 Year Starship conference in 2011. The inventor of the PFRC, Dr. Sam Cohen of PPPL, is a key advisor and collaborator.

VISION

A bold, inspiring world of space exploration enabled by DRD/PFRC technology



Fusion propulsion will cause a paradigm shift in deep space missions. Missions will be simpler, faster, less expensive, and return more data. Similarly, a small, portable fusion reactor will be game-changing for surface power, enabling manned missions and supporting industrial applications. The PFRC will enable big, bold missions without requiring the launch of any radioactive material.

A family of PFRC reactors of different sizes and using different fuels can one day provide an ecosystem of fusion power, from single-reactor off-grid remote applications to modular power plants built from dozens of PFRCs. Our vision is to make that a reality.

USE OF FUNDS

Match federal INFUSE investment and gather critical data from the PFRC experiment for designing the next-generation superconducting machine.

Our immediate goal for the proceeds is to support our newly awarded DOE INFUSE grants. In this program, the grant money goes to a federal research lab or university to perform essential work for a commercial company, and the company must contribute its own share of the work – "cost-share". We have been awarded $600,000 in federal funds which requires us to contribute $200,000 over about 18 months. This supports critical modeling and analysis in heating system optimization for the PFRC as well as bringing a diagnostic to the PFRC-2 machine to measure electron profiles.

With additional funds, we will take data with the ARPA-E funded ion energy diagnostic at maximum machine parameters – the highest magnetic fields and heating power we can generate. This data will both demonstrate the performance of the current heating system and help us design the next machine, PFRC-3, which will heat plasma to fusion conditions. The graphic shows a rough breakdown of funds for three scenarios between modeling, experiment operations, hardware, and general business expenses. In the highest funding scenario, we will be able to purchase and test equipment for the PFRC experiment that can then be applied to the PFRC-3 – such as new more efficient antenna designs and power electronics.

COMPANY

Princeton Satellite Systems, Inc.

Subsystems/Power Systems

Princeton Satellite Systems, Inc. is a small company extending the state-of-the-art in energy and aerospace systems. We are actively developing exciting technology for electricity backup, electric vehicle charging, fusion propulsion, lighter-than-air-vehicles, solar sails, spacecraft formation flying, launch vehicles and spacecraft control and navigation.

Website	psatellite.com
Employee Count	5 People
Founding year	1992
Company type	Private

View Company Profile

RISKS & DISCLOSURES

Nuclear fusion development is a substantial risk that we can offset with partnerships with other fusion entities.ield-reversed configurations (FRCs).

<u>Risks associated with product</u>

Our product is not yet ready for commercial deployment.

We do not have an operating fusion reactor. Additional research and development are needed to produce a functioning fusion reactor and to design a reactor usable for space applications. We may encounter unexpected delays, or may never have a product accepted by the market. If there is a lack of uptake by potential customers of a new product, the company may not succeed.

The PFRC reactor concept has not yet achieved fusion or propulsion.

Additional research and development are required to demonstrate that PFRC can achieve fusion with a net gain. We may discover unexpected plasma instabilities or the single heating method may not couple efficiently enough to the plasma. The fusion propulsion system cannot be fully tested until the reactor is producing fusion. The propulsion efficiency may not be high enough for practical use.

<u>Operational Risks</u>

PSS has its foundation as a software and consulting company with limited experience producing hardware.

PSS was formed in 1992 as an aerospace consulting company and launched its first commercial software product in 1995. Our first contract relating to fusion propulsion was in 2016. Our current and proposed operations are subject to all the business risks associated with technology enterprises. These include likely fluctuations in operating results as the Company reacts to developments in its market, manages its growth, and the entry of competitors into the market. We expect to incur net losses until we can establish a consistent base of customers for the Company's product. There is no assurance that we will be profitable or generate sufficient revenues to support our operations.

Economic and Industry risks

Evolving regulations governing nuclear fusion power may impact the Company's business and prospects.

We anticipate U.S. and International fusion regulations will evolve and may impact our operations and business success. If new or changed regulations are introduced, they may limit our ability to market and sell our products and services to customers, as well as possibly limit our customer's ability to apply our products and services.

We are dependent on general economic conditions.

Our business model is dependent on our target customers being able to finance their own operations and interest. Our business model is thus dependent on national and international economic conditions. Adverse national and international economic conditions may reduce the future interest of our target customers, which would negatively impact our revenues and possibly our ability to continue operations. These fluctuations may be significant and could impact our ability to operate our business

1. No money or other consideration is being solicited, and if sent, will not be accepted;
2. No offer to buy the securities can be accepted and no part of the purchase price can be received until the offering statement is filed and only through an intermediary's platform; and
3. A prospective purchaser's indication of interest is non-binding.

Because money cannot be collected until the Form C is filed, investors who express interest during Pre-Launch will receive an email with instructions on how to confirm and officially invest. Not all companies that Pre-Launch will go on to file a Form C and launch a campaign, especially if they discover that there is not enough investor interest.

DOCUMENTS