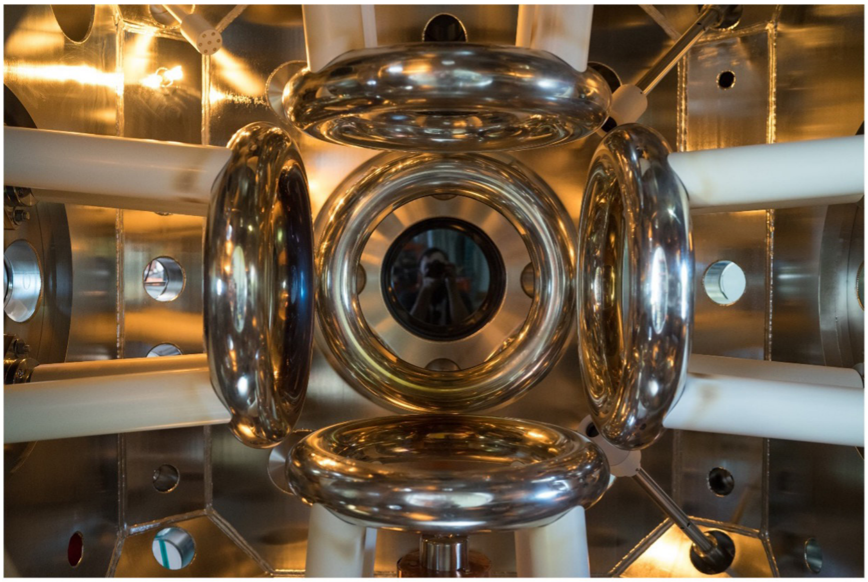
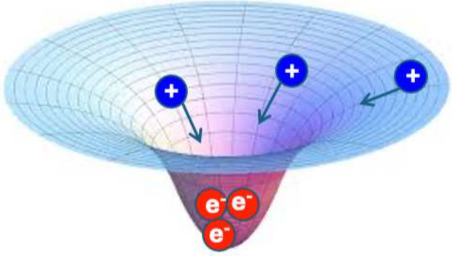
INTERVIEW WITH EMC2 FUSION

A Different Approach to Fusion

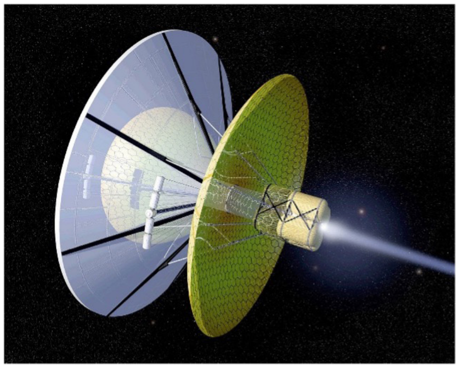


Last week we had a discussion with Dave Mansfield of EMC2 Fusion, which came out of The Fusion Report article on "The Fusion Navy". EMC2 Fusion's approach (pictured right) is called a "Polywell"; it is a device that utilizes magnetic coils in Polyhedral cusp configuration, combined with an electric "well" generated by electron beams. The result is that fuel, whether deuterium-tritium (D-T) or proton-boron (p-B), is confined by and accelerated into this "well" at extremely high speed, fusing the fuel. The configuration shown above is a six-coil one, but other configurations such as the dodecahedral cusp using twelve coils are also possible. From a size perspective, a system with coils roughly 2 meters in diameter should theoretically be able to generate 100 mega-watts (100 MW) of fusion energy.



God Doesn't Build in Straight Lines (or Use Toroids)

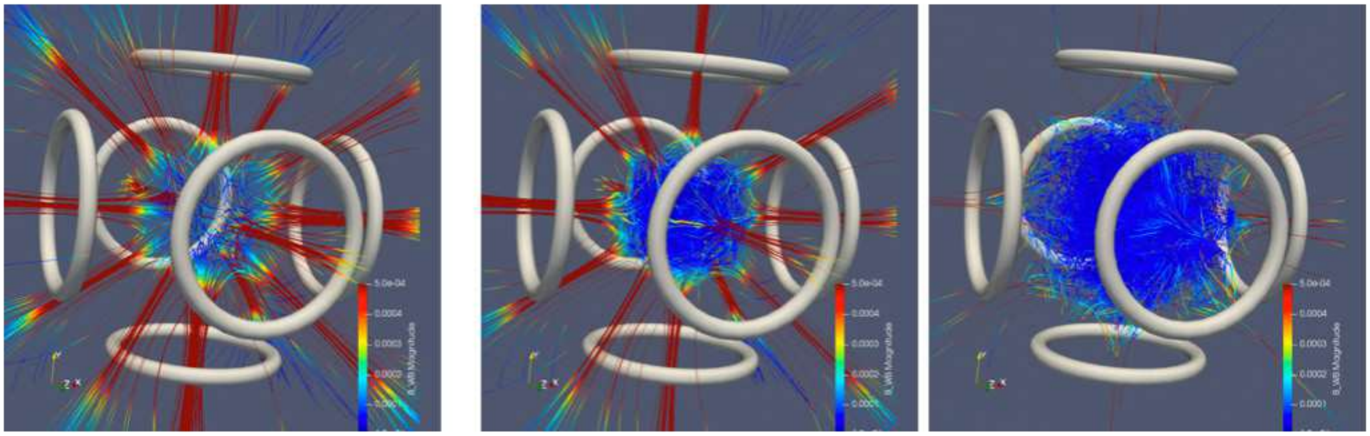
In the movie "Prometheus", one of the scientists on the mission to the moon LV-223 remarks on the organization of the structures on the surface by saying "God doesn't build in straight lines", remarking how the structures there must be artificial because they were all in a straight line. Similarly, one of the more interesting things that Dr. Robert Bussard, the American physicist who thought of the Polywell, stated was that "But fusion works. All you have to do is go outside at night and look up. There are billions of fusion reactors. Every star is a fusion reactor, every single one of them, and not one of them is 'Toroidal'." Of course, the thing that we don't have to make spherical fusion reactors like those in space is the gravity that a star has. That is where the physics of the Polywell fit in.



Interestingly, one of the concepts for which Bussard is most famous is the *Bussard Ramjet*, a theoretical approach to interstellar travel. The concept of the Bussard Ramjet is that it creates an extremely large magnetic field that acts as a "funnel" (think tens to potentially thousands of kilometers in diameter) which scoops up ionized particles. The particles are mechanically compressed in a narrow "reactor" that causes fusion of the particles. Several analyses of this concept have identified some problems with it, such as a much lower density of interstellar particles than expected in the early 1960s, difficulties fusing protons due to bremsstrahlung losses (which reduce particle kinetic energy), issues with accelerating into a solar wind, and practical construction issues that cast doubt on its viability. That is when Dr. Brussard switched from interstellar fusion-based propulsion to more earthbound concerns, specifically the Polywell.

The Smaller, The Cheaper – Is it Really Better?

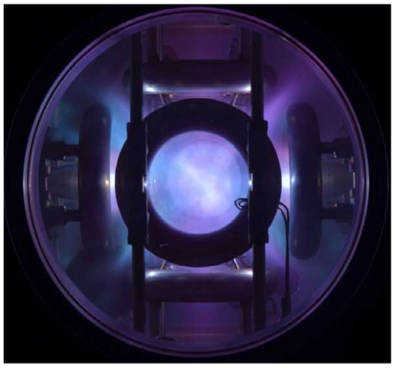
The Polywell concept stems from the research originally pursued by mathematicians from New York University in the 1950s, known as the high-beta cusp reactor. The magnetic cusp is the only known magnetic field configuration where the plasma stability is intrinsically assured due to favorable magnetic field curvature, a key advantage for small and economical fusion reactors. One of the best-known examples of a magnetic cusp is the Earth's magnetosphere, where the solar wind plasma is blocked from hitting the Earth's surface. Bussard described the key feature of the high-beta cusp as the "wiffle-ball" confinement, where high plasma pressure and associated plasma diamagnetism pushes the quasi-spherical magnetic fields outward and shrinks the holes along the seams of the Polywell cusps. See the illustration below showing the topological change in magnetic field structure in the presence of high-pressure plasma. This change in magnetic field structure leads to improved plasma confinement of the high-beta cusp or the WB.

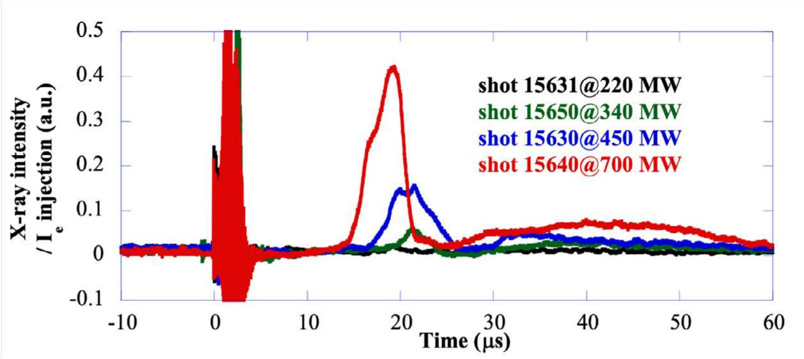


His breakthrough in Polywell fusion occurred when he realized that the primary loss mechanism of the high-beta cusp can be suppressed by adding an electric potential well from the inertial electrostatic confinement (IEC) concept. As the ion moves outward toward the cusp boundary, the potential well slows down ion velocity and pulls it toward the center for fusion reactions, while suppressing its loss. In comparison, the electron, which gains energy as it moves outward, would still be efficiently confined in the high beta cusp due to its much smaller momentum and gyroradius. By adding the electric potential, Bussard fixed the primary flaw of the high-beta cusp and invented the Polywell, an intrinsically stable, compact and easy-to-scale fusion approach.

In practice, however, forming the high beta cusp was much more difficult than Bussard envisioned. It took EMC2 almost 30 years of R&D, following the construction and testing of twenty experimental devices, to complete the critical step of forming a successful WB, which was accomplished in 2013, some time after the passing of Bussard in 2007.

See the illustrations below from the EMC2's peer-reviewed paper ["High-Energy Electron Confinement in a Magnetic Cusp Configuration", Park et al, Phys. Rev. X 5, 021024]. The left is the snapshot of the WB inside the 6-coil Polywell test, and the right is the change in x-ray signal intensity over time, showcasing the improved plasma confinement. The successful formation of the WB due to the dedicated start-up system operating at 700 MW of pulse power, compared to failed attempts at 220 MW and 340 MW. This incredibly high power threshold is the reason why it took 30 years for EMC2 to achieve this feat, and others who tried to imitate the Polywell failed.





Next Steps for EMC2 Fusion

The challenge that EMC2 faces, like most fusion companies, is that fusion is a "long bet."has, like most of the fusion companies out there, is that fusion is a "long bet". While EMC2 started out on government grants around 199085, that funding ran out around 2015. As such, EMC2 has looked for additional applications to raise the additional funds to build their next-generation Polywell device to continue its pursuit of fusion power. One of the areas that has shown promise for EMC2 (as well as for a number of other fusion companies) is using their technology for the development and construction generation of high flux neutron sources. A Polywell with a dense plasma target can produce 1,000 times higher neutron yield than commercially available neutron generators. This capability can be valuable for a number of applications such as tritium breeding, the testing of materials for nuclear fission reactors , and for processing and rendering safe nuclear waste the safeguarding of our nation's nuclear arsenal. As an example, one program that EMC2 is pursuing, along with SHINE Technologies (another fusion company), is the Fusion Prototypic Neutron Source (FPNS) program of the U.S. Department of Energy (DoE) Office of Science. The purpose of FPNS is to test materials for fusion reactors by bombarding them with neutrons having the energy that is typical of D-T fusion reactions, 14.1 million electron volts (14.1 MeV).

Summary

As we discussed in a few of our previous articles, fusion energy is not a "poor man's game". The amount of money that it will take to fully commercialize fusion energy is likely in the billions; anything to reduce the size of a reactor only helps reduce the amount of capital required to reach that goal. One of the theories that commercial programs embraced was that they didn't need to build something as big or expensive as ITER to be successful in fusion. If EMC2 and the Polywell do achieve their promise, it represents another step in the evolution of fusion systems. Given that fusion in general has been a big "learning process", hopefully this particular experiment will torn turn out well.

1. **Tell us about the origin of your company.**

   Dr. Robert Bussard was the founder and inventor of the Polywell fusion approach (Dr. Bussard is credited with inventing the Bussard Ramjet, a spacecraft propulsion method designed for interstellar travel).

   In the 1970s, Dr. Bussard collaborated with Hirsch and Trivelpiece at the Atomic Energy Commission, overseeing the approval of the Tokamak Fusion Test Reactor (TFTR) project, which achieved 10.7 MW of fusion power in 1993. In 1985, he founded EMC2, driven by the insight that a Polywell device could generate net fusion energy by integrating a high beta magnetic cusp (which he referred to as the Wiffle-Ball (WB) effect) with a potential well.

   Dr. Bussard convinced the US Navy that the device would make an ideal compact power source for naval propulsion and received funding to iterate a series of 20 Polywell devices from 1985 to 2015. After his passing in 2007, R&D at EMC2 passed to Dr. Jaeyoung Park who successfully produced the important Wiffleball experimental results demonstrating the viability of the approach pioneered by Dr. Bussard.

COMPANY INFORMATION

FOUNDED
1985

EMPLOYEES
5+

FUNDING
$35,000,000

HEADQUARTERS
San Diego, CA

info@emc2fusion.com

www.emc2fusion.com

www.linkedin.com/company/emc2fusion/about

2. **Who are your investors?**
Much of the capital raised thus far for EMC2 has been through the US government programs (DARPA, US Navy Research) which funded the development of multiple Polywell devices in the period 1985 - 2015. As a non-government funded entity, EMC2 has primarily raised capital from High Net Worth individuals and continues to seek funding from other institutional sources. The funding raised to date has been used to produce the core experimental results along with a cutting edge PiC computer simulation framework which EMC2 uses to perform first principals, full-lifecycle simulation of a working Polywell device.

3. **What makes your approach unique to the market?**
The Polywell approach to confinement and heating of fusion plasmas is unique in the landscape of fusion approaches. The core advantages are:
    - **High Beta Plasma.** The confinement of plasmas in a Polywell device is done in a High Beta state, this drives incredible Fusion Energy performance relative to the size of the device.
    - **Cusped Magnetic Fields.** The natural shape of the magnetic field configuration allows for simple heating of the plasma using electron beam injection.
    - **Simple Device.** The simplified geometry and intuitive stability of a spherical confinement provides for a much more tractable computation problem. HPC simulations are far simpler and can be done comprehensively on a first principles basis.
    - **Low Capital Cost.** The combination of the above factors allows for a compact fusion device which can be built for a dramatically lower capital footprint than other devices of comparable fusion output.

    With the above advantages, the Polywell approach presents a unique opportunity for an accelerated path to commercial fusion with a capital-light, iterative approach driven be insights from powerful high-fidelity simulations.

4. **Who are your target customers?**
There are 2 primary commercial objectives which are being pursued by EMC2, one is a medium term objective, the other with a longer time to delivery:
    - **High Flux Neutron Sources:** The Polywell is ideally suited to produce an industry leading compact neutron source of high flux. There is demand within the fusion energy industry for such a device which might be used for Materials Testing and Tritium Breeding research. EMC2 has made a joint submission for the US Government FPNS program for which we anticipate imminent release of the recommendations of a Review Panel.
    - **Power provision for AI Data Centers:** With the rapid rise in the anticipated Electricity provisioning required to meet growth in AI and Data Center use-cases. EMC2 have a design of a 100MWe power reactor which could be used to fill this shortfall.

5. **When will commercial fusion electricity be on the grid?**
While we believe that fusion energy will be used to provide power to individual projects between 2030-2035 e.g. Data Centers, power to the grid will probably be post 2035.