The Fork in the Road to Electric Power From Fusion

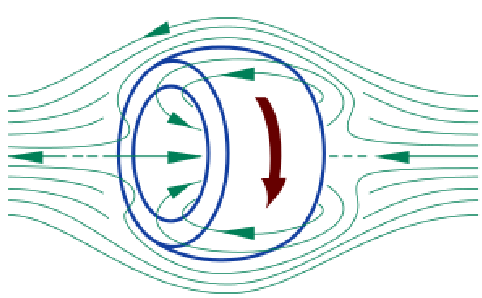
Compact Fusion Systems (CFS)

Peter Lobner, 1 February 2021

Compact Fusion Systems (CFS) is a Santa Fe-based energy technology company founded in 2017 by Simon Woodruff and Peter Turchi to develop a stabilized liner compressor (SLC) fusion machine called the Fusion Power Core, in partnership with the University of Maryland. CFS is a spinout venture from Santa Fe-based Woodruff Scientific, Inc., which specializes in pulsed power, magnetics and scientific instrumentation. The CFS spin out was supported by a $20,000 seed investment from Strong Atomics. The CFS team includes members who have had experience with SLC devices at the Air Force Research Lab (AFRL) at Kirkland Air Force Base and Naval Research Lab (NRL). The CFS website is here: https://www.compactfusionsystems.com/#start

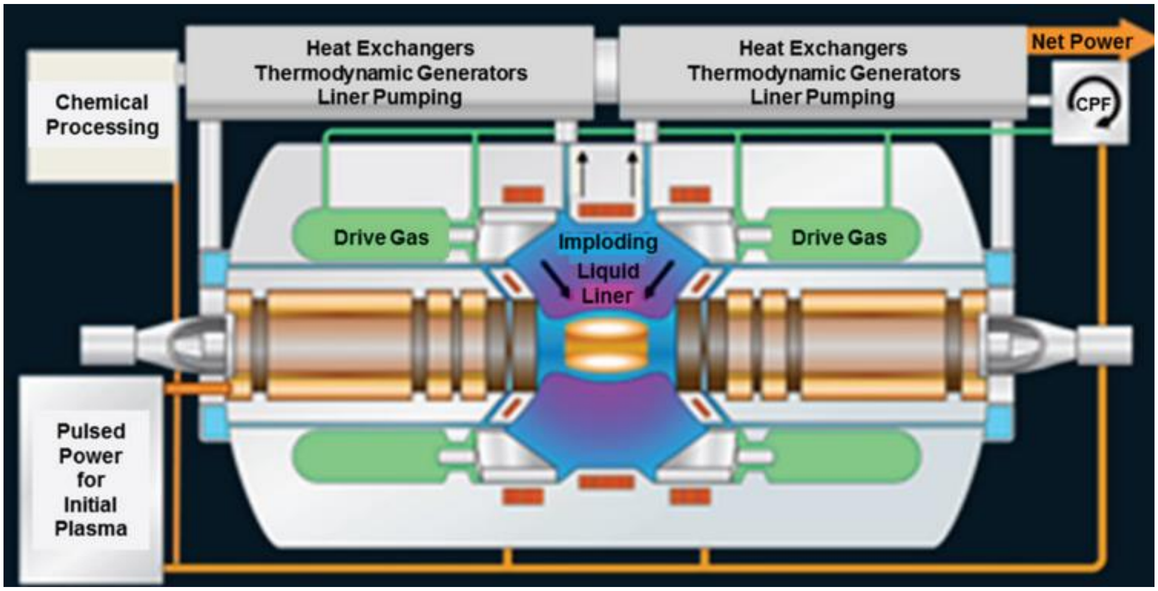
CFS and General Fusion are taking different approaches to the use of SLC technology in their designs of compact fusion power plants that may demonstrate power generation in the next decade.

The CFS Fusion Power Core is based on the mechanical compression of colliding field reversed configuration (FRC) plasma targets, likely deuterium-tritium (D-T). A plasma gun creates each FRC plasma target in the form of a self-stable, rotating plasma torus, similar to a smoke ring.



FRC: a toroidal electric current is induced inside a cylindrical plasma, making a poloidal magnetic field, reversed in respect to the direction of an externally applied magnetic field. The resultant high-beta axisymmetric compact toroid is self-confined. Source: Wikipedia

The general arrangement of the Fusion Power Core is shown in the following diagram.

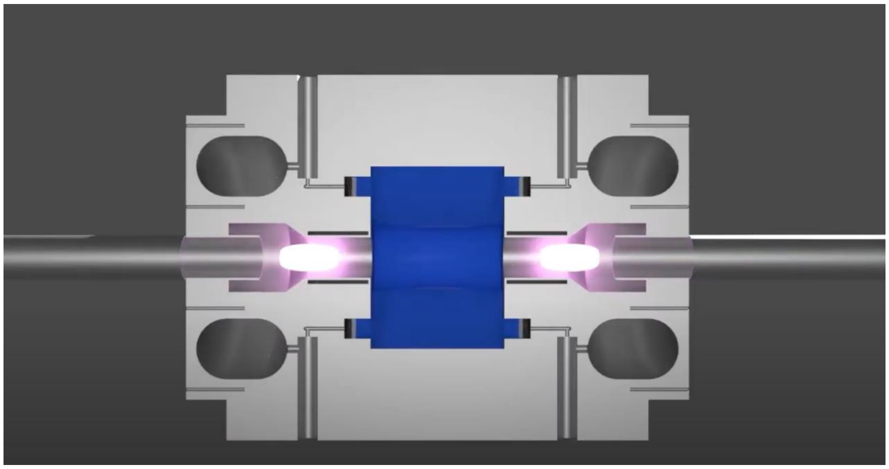


Source: CFS

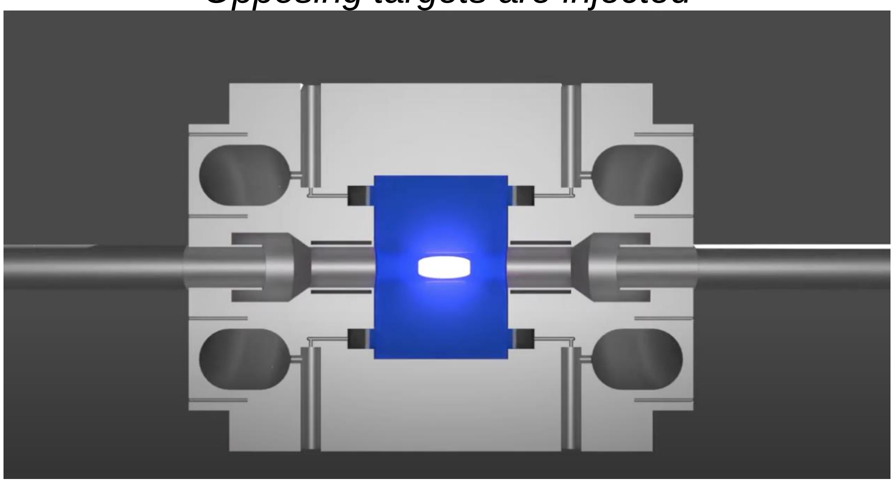
The plasma guns (injectors) are located at opposite ends of the axial shaft running through the machine. The imploding liquid liner (blue) in the center of the machine is a flowing, rotating mass of liquid metal with a void space in the middle (gold) where the FRC plasma targets collide after being fired from the plasma guns. At the instant of collision, pneumatically driven pistons are actuated to implode the liquid metal liner (i.e., force it inwards) to adiabatically compress the merged plasma target to fusion conditions. The energy of the fusion reaction (mainly neutrons for D-T and D-D reactions) is captured in the liquid metal, which “strokes” back to its pre-implosion position in preparation for the next pulse cycle.

Energy absorbed during fusion is carried off in the continuous, closed-loop flow of liquid metal between the Fusion Power Core and heat exchangers that establish the heat transfer path into a secondary steam and power conversion, similar to the type found in modern fission or fossil power plants. This is where electric power is generated.

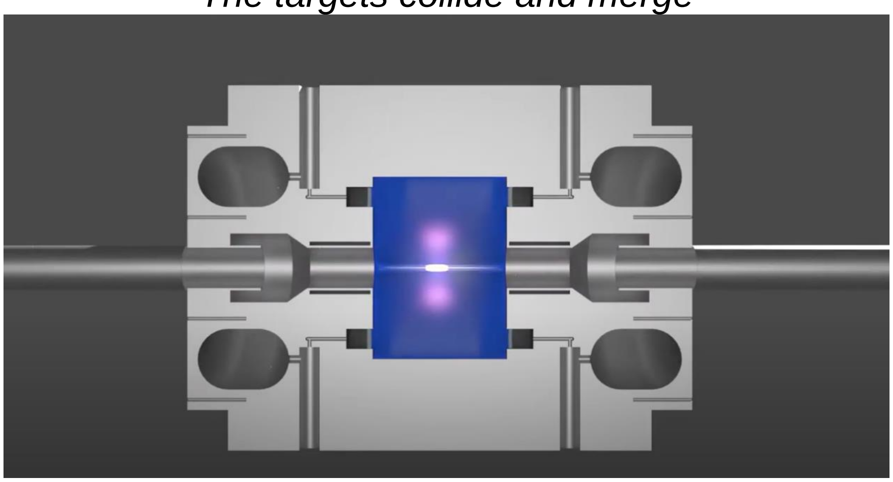
The operation of the colliding FRC plasma injection system is illustrated in the following sequence of drawings.



Opposing targets are injected

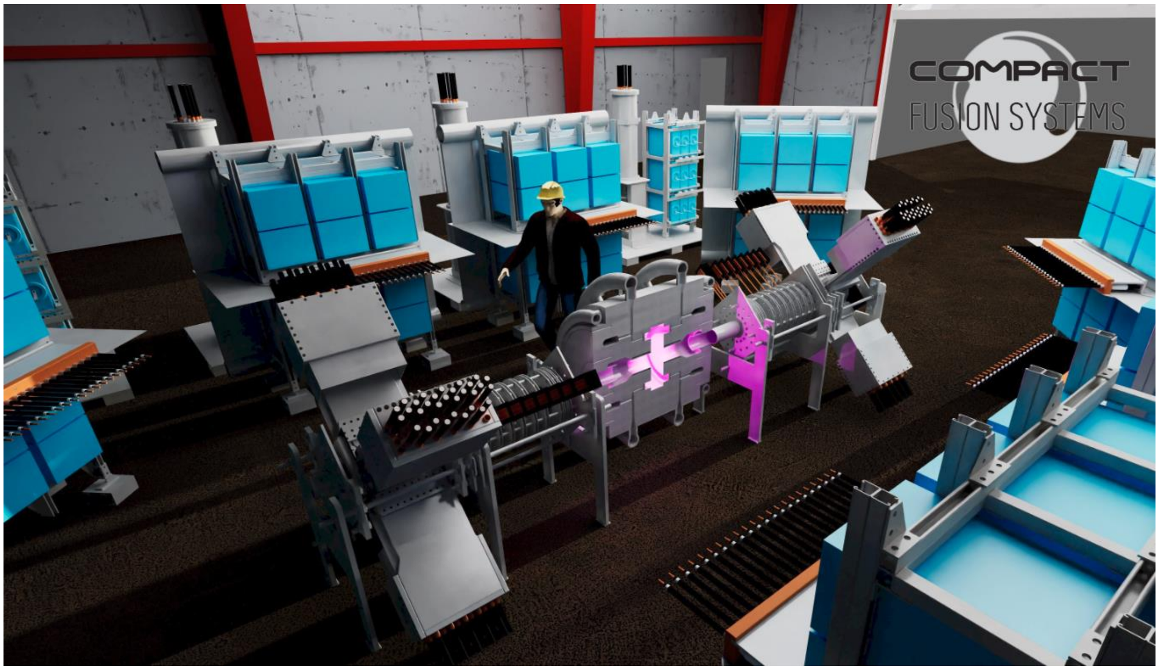


The targets collide and merge



Merged target is adiabatically compressed. Source: CFS

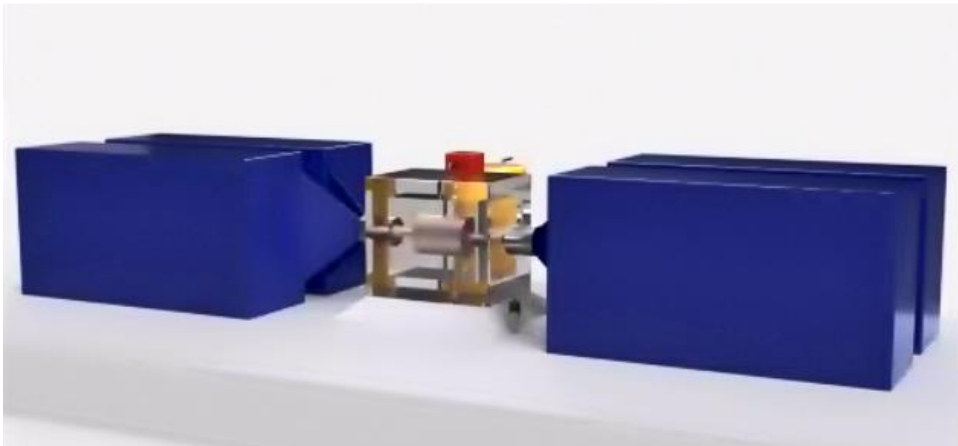
CFS is planning to build a three meter (9.8 ft) long proof-of-principle Fusion Power Core machine, which will cost about $9 million, $5 million to bench test the liquid metal compressor and $4 million to conduct system integrated testing.



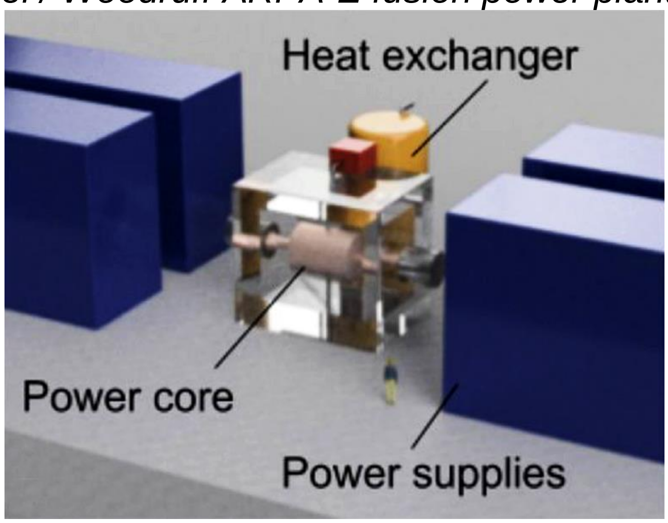
Rendering of the CFS proof-of-principle machine. Source: CFS

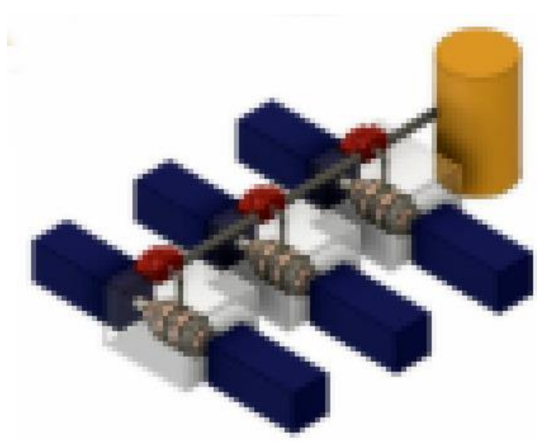
The proof-of-principle machine is expected to be capable of 25:1 volumetric compression at an implosion velocity of 1.4 km / second (0.14 cm/microsecond, more than a factor of 20 slower than a staged Z-pinch machine).

CFS provided input to a DOE ARPA-E fusion costing study performed by Bechtel and Woodruff Scientific. A conceptual design of a 150 MWe fusion power plant employing a Fusion Power Core was developed as part of that study. The basic layout is shown in the following graphics. In these graphics, the biological shield around the fusion reactor is shown as a transparent box and a model of a six-foot person is included for scale reference. A summary of that cost study is available here: https://nucleus.iaea.org/sites/fusionportal/Shared%20Documents/Enterprises/2018/Presentations/14.06/Woodruff.pdf



One modular CFS power plant.
Source: Bechtel / Woodruff ARPA-E fusion power plant costing study





Several fusion reactor modules can be combined in a single power plant for greater gross electric power output. Source: CFS.

CFS claims that the Fusion Power Core will be available starting in 2030. The levelized cost of electricity (LCOE) is expected to be <5c / kWh. Power plant operating life is expected to be more than 25 years.

Funding

In addition to the $20,000 seed funding provided by Strong Atomics when the company was founded, CFS has received funding from the following sources:

- New Mexico Economic Development Department by participation in the Small Business Assistance program.
- DOE ARPA-E grant to fund the relocation and re-use of equipment from the Air Force Research Lab (AFRL) to build the proof-of-principle stabilized liner compressor device.

For more information

- Video: "Concept Introduction - Compact Fusion Systems" (10:42 minutes), 6 November 2019: https://www.youtube.com/watch?v=cdMs5e_3LJw
- Video: "Proof of Principle Concept Design Flyby - Compact Fusion Systems," (1:44 min), 6 November 2019: https://www.youtube.com/watch?v=D2YJI5LEBm4&feature=emb_logo

Patents

- US2011/0142185A1, "Device for compressing a compact toroidal plasma for use as a neutron source and fusion reactor," filed 17 February 2010, published 16 June 2016, assigned to Woodruff Scientific, Inc., current status: abandoned: https://patents.google.com/patent/US20110142185?oq=Dr.+Simon+Woodruff