XTUS ENERGY

Mission: To develop innovative and compact fusion power core technologies, with the view to licensing or selling the technology as soon as possible.

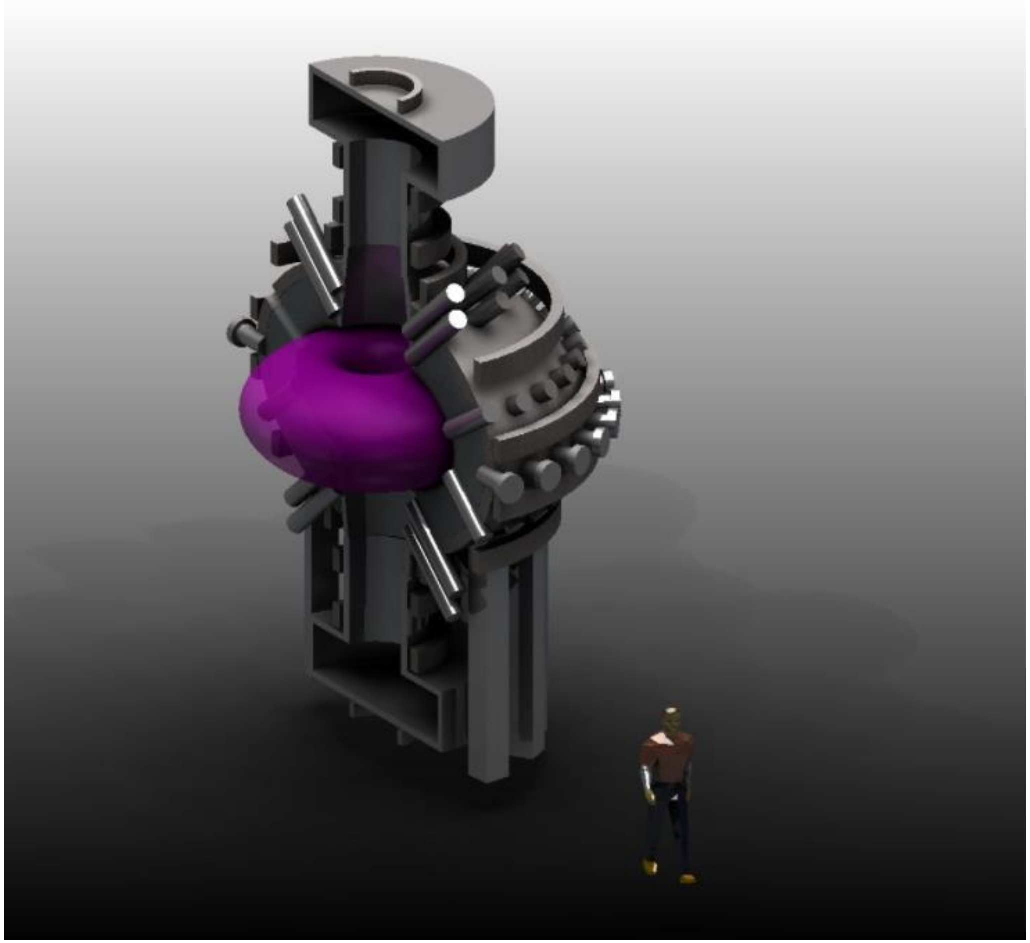
Problem worth solving

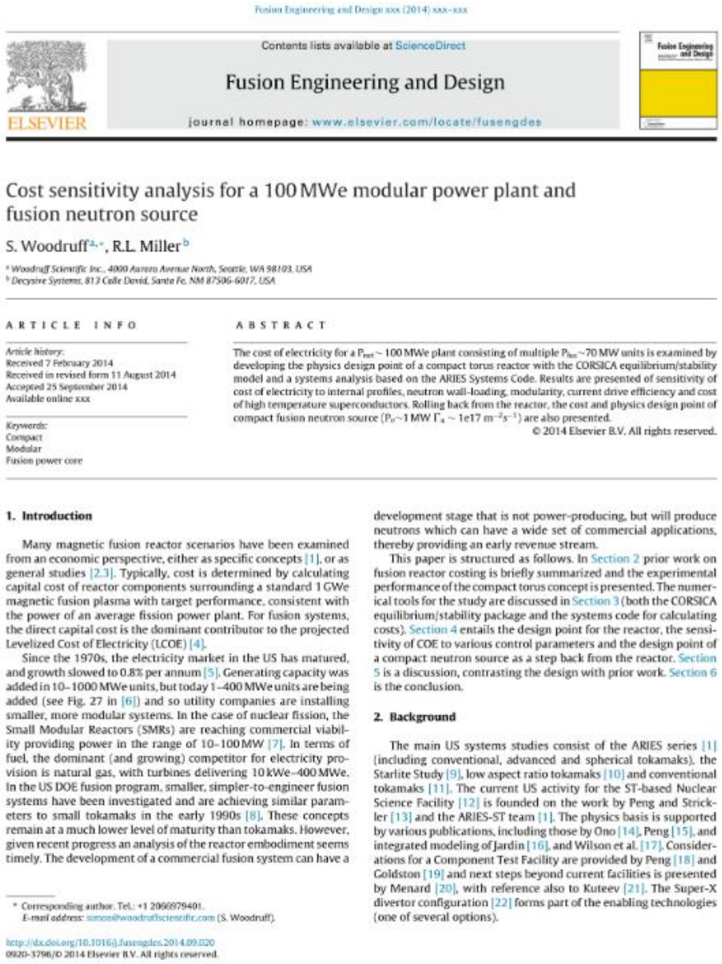
Prototyping of a new fusion concept is capital and labor intensive, and fraught with technical and capital risks. Solutions are posed as decadal development efforts and are limited to only those investors with long time-lines and deep pockets. New energy technologies are needed now, not in 15-20 years.

Our solution

Xtus Energy Inc aims to mitigate both technical and capital risks on the path to fusion energy by regularly evaluating our technical solutions to identify those that can be sold, licensed or spun out. This ensures that cash neutrality is reached as soon as possible, and also expedites fusion power core development as each IP concentration attracts customers or further investment.

Our technology: 100MWe fusion generators





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Cost sensitivity analysis for a 100 MWe modular power plant and fusion neutron source

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ABSTRACT

The cost of electricity for a $P_{net} \sim 100$ MWe plant consisting of multiple $P_{fus} \sim 70$ MW units is examined by developing the physics design point of a compact torus reactor with the CORSICA equilibrium/stability model and a systems analysis based on the ARIES Systems Code. Results are presented of sensitivity of cost of electricity to internal profiles, neutron wall-loading, modularity, current drive efficiency and cost of high temperature superconductors. Rolling back from the reactor, the cost and physics design point of compact fusion neutron source ($P_n \sim 1$ MW $\Gamma_n \sim 1e17\ m^{-2}s^{-1}$) are also presented.

1. Introduction

Many magnetic fusion reactor scenarios have been examined from an economic perspective, either as specific concepts [1], or as general studies [2,3]. Typically, cost is determined by calculating capital cost of reactor components surrounding a standard 1 GWe magnetic fusion plasma with target performance, consistent with the power of an average fission power plant. For fusion systems, the direct capital cost is the dominant contributor to the projected Levelized Cost of Electricity (LCOE) [4].

Since the 1970s, the electricity market in the US has matured, and growth slowed to 0.8% per annum [5]. Generating capacity was added in 10–1000 MWe units, but today 1–400 MWe units are being added (see Fig. 27 in [6]) and so utility companies are installing smaller, more modular systems. In the case of nuclear fission, the Small Modular Reactors (SMRs) are reaching commercial viability providing power in the range of 10–100 MW [7]. In terms of fuel, the dominant (and growing) competitor for electricity provision is natural gas, with turbines delivering 10 kWe–400 MWe. In the US DOE fusion program, smaller, simpler-to-engineer fusion systems have been investigated and are achieving similar parameters to small tokamaks in the early 1990s [8]. These concepts remain at a much lower level of maturity than tokamaks. However, given recent progress an analysis of the reactor embodiment seems timely. The development of a commercial fusion system can have a development stage that is not power-producing, but will produce neutrons which can have a wide set of commercial applications, thereby providing an early revenue stream.

This paper is structured as follows. In Section 2 prior work on fusion reactor costing is briefly summarized and the experimental performance of the compact torus concept is presented. The numerical tools for the study are discussed in Section 3 (both the CORSICA equilibrium/stability package and the systems code for calculating costs). Section 4 entails the design point for the reactor, the sensitivity of COE to various control parameters and the design point of a compact neutron source as a step back from the reactor. Section 5 is a discussion, contrasting the design with prior work. Section 6 is the conclusion.

2. Background

The main US systems studies consist of the ARIES series [1] (including conventional, advanced and spherical tokamaks), the Starlite Study [9], low aspect ratio tokamaks [10] and conventional tokamaks [11]. The current US activity for the ST-based Nuclear Science Facility [12] is founded on the work by Peng and Strickler [13] and the ARIES-ST team [1]. The physics basis is supported by various publications, including those by Ono [14], Peng [15], and integrated modeling of Jardin [16], and Wilson et al. [17]. Considerations for a Component Test Facility are provided by Peng [18] and Goldston [19] and next steps beyond current facilities is presented by Menard [20], with reference also to Kuteev [21]. The Super-X divertor configuration [22] forms part of the enabling technologies (one of several options).

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Target markets

- CO2-free Energy (>$Tn)
- Hydrogen for transportation (>$Tn)

Competitive landscape

Competitors	**How our solution is better**
Private sector	We have 20+ years of experience, not newbies!
National Labs	Lower cost, faster
Academia	Student workforce is cheap, but industry is better place for quality management

Sales / Marketing channels

Sales channels will be direct to customer, through the Fusion Industry Association and through ARPA-E supported programs.

Traction: fusion-related businesses

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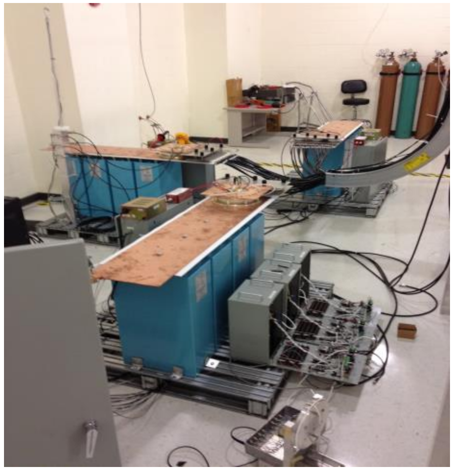
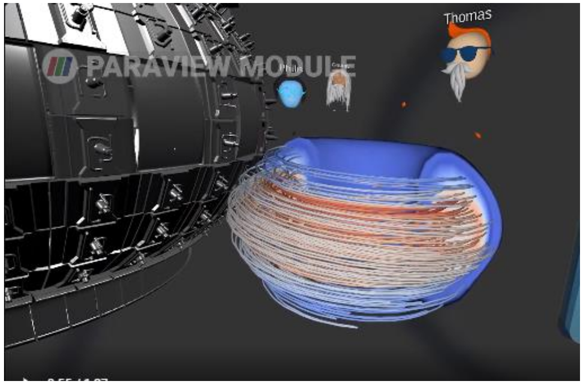


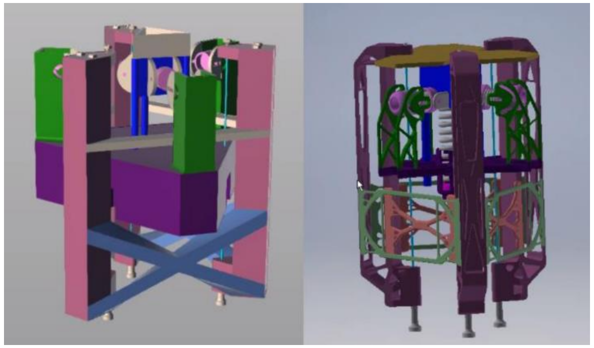
Pulsed power, magnets and sensors, and simulations for fusion systems. Started with SBIRs.

SciVista



Data visualization and integrated simulation and modeling tools in Virtual Reality. Started with SBIRs

UHV3D



Automated design optimization for metal AM for components in Ultra-High Vacuum environments. Started with SBIRs.

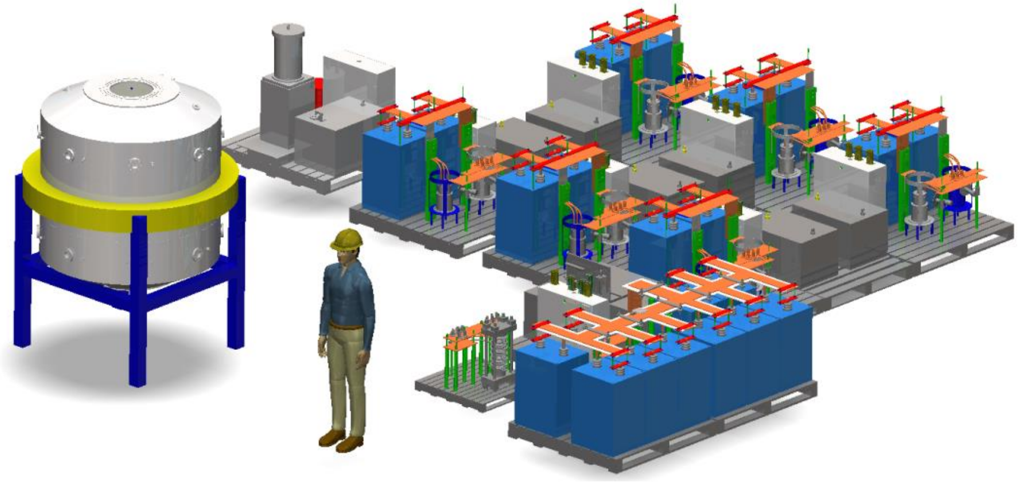
Progress to date

Concept design of fusion neutron source completed for purposes of waste transmutation. Early customer discussions (e.g. Hanford).

Engineering design completed for the major subsystems for portable (transportainer) neutron source.

Electrical engineering for high power modular banks completed and pulsed-power equipment moved from AFRL to our lab in Santa Fe.

Risk mitigation: fusion neutron sources



Adiabatic Compression of a Compact Torus

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Abstract

A design point is presented here for a prototype fusion neutron source for waste transmutation ($10^{17} - 10^{19}$n/s), based on the adiabatic compression of a compact torus (spheromak). The design utilizes the CORSICA (2D equilibrium) and NIMROD (3D time-dependent MHD) codes as well as analytic modeling with target parameters $R_{initial}$=0.5m, R_{final}=0.167m, $T_{initial}$=0.4keV, T_{final}=4keV, $n_{initial}=2\times10^{20}$m^{-3} and $n_{final}=50\times10^{20}$m^{-3}, with radial convergence of C=3. 3D time-dependent simulations of spheromak compression agree well with analytic models for adiabatic compression, if the run-in time $\tau_{compress} < \tau_E$. Knowing $\tau_{compress}$ required, we design coils and passive structure (with CORSICA) to ensure stability; then design the capacitor bank needed to both form the target plasma and drive coils. We specify target parameters for the compression in terms of plasma beta, formation efficiency and energy confinement.

Keywords: Compact, Neutron Source, Fusion

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1. Introduction

The development of compact fusion neutron sources for use in waste transmutation and fuel reprocessing has motivated an IAEA Coordinated Research Project (CRP) aiming for sources with P_n=1-100MW ($10^{17} - 10^{19}$n/s) [1]. As part of this study a number of different candidates are being considered, based on the Tokamak, mirror, and spherical torus (ST). Our concept is based on the adiabatic compression of a compact torus, in this case a Spheromak [2]: essentially a tokamak with reversed shear, q spanning q_0=0.6 to q_{95}=0.3, and the currents that produce the toroidal field flow in the plasma rather than in external windings. We examine a low radial convergence C_R (=R_0/R_f) < 3, which differentiates our concept from magnetized target fusion concepts with C=10 or more. The focus of this paper is on the design point for an experiment that will resolve matters of confinement scaling and peak pressure before building a full neutron source [3].

This paper is therefore structured as follows. In Section 2 prior work on adiabatic compression in spheromaks (S1), and tokamaks (TUMAN-3M and ATC) is briefly summarized; recent spheroamak performance presented. The numerical tools for the study are discussed in Section 3 (CORSICA, NIMROD and the analytic adiabatic scaling model). In Section 4, a 0D design point for a neutron source is defined analytically; time-dependent 3D MHD simulations results are presented (to test for adiabaticity); and a 2D equilibrium model is used to define coil positions to support equilibrium and provide compression. Given coil currents from CORSICA, a bank design is developed that allows for compression faster than τ_E. Knowing the size of bank and coils, an engineering design point is developed. Section 5 is a discussion, contrasting the design with work ongoing in the IAEA CRP. Section 6 is a discussion of the work that follows prior to finalizing physics and engineering design points. Section 7 is the conclusion.

2. Background

Accessing high $n\tau T$ adiabatically with a 1m system has been the aim of several experiments in the past. ATC [4] saw ion temperatures increase from 200eV to 600eV, TUMAN-3M [5] observed a transition to H-mode confinement and S1 (Fig. 1) was able to obtain adiabatic compression of spheromaks with C=1.6, and corresponding increase in T_e from 40 to 100eV [6]. Currently ARPA-E is supporting compression concepts, and companies are finding investment for the development of compact tori utilizing compression. Omitting the central stack (toroidal field coil, solenoid, blankets and shield) reduces cost and engineering complexity of the power core [7]. The per-

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Kyoto Fusioneering

SciVista

DAVIS & MUSGROVE LTD.

Near term milestones

Propose complete system to ARPA-E in the OPEN call, deadline in August

Complete neutron source design point by October 2021

Propose relevant technologies in the INFUSE call (August) and SBIR rounds (Feb 2022)

Further information

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