CHANGING WHAT'S POSSIBLE

ALPHA: Accelerating Low-Cost Plasma Heating and Assembly

Fusion Power Associates 37th Annual Meeting and Symposium
Fusion Power Development: An International Venture

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ARPA-E

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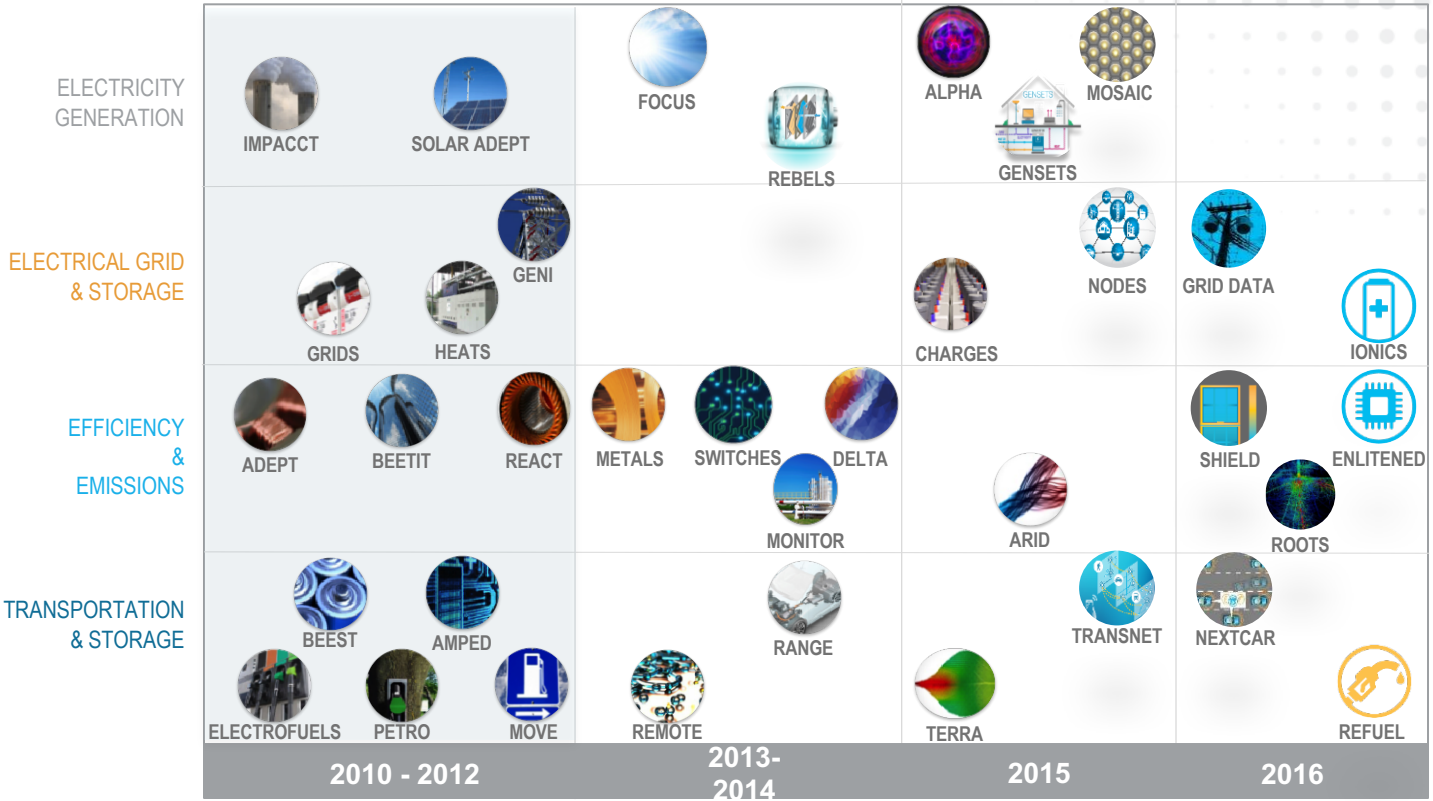
Evolution of ARPA-E

In 2007, The National Academies recommended Congress establish an Advanced Research Projects Agency within the U.S. Department of Energy

…"The new agency proposed herein [ARPA-E] is patterned after that model [of DARPA] and would sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship, where risks and potential payoffs are high, and where success could provide dramatic benefits for the nation."…

	2007	2009	2010	2011	2012	2013	2014	2015	2016
Awards Announced		37		12	16	20	23	32	39
Programs To Date		1	7						500+
	Rising Above the Gathering Storm **Published** *America COMPETES Act* **Signed**	*American Recovery & Reinvestment Act* **Signed**		*America COMPETES Reauthorization* **Signed**					*Anticipated*
	$400 Million (Recovery Act)	$180 Million (FY2011)	$275 Million (FY2012)	$251 Million (FY2013)	$280 Million (FY2014)	$280 Million (FY2015)	$291 Million (FY2016)		

Focused Program Portfolio



ALPHA seeks more options for fusion energy

Fusion energy would be transformational:

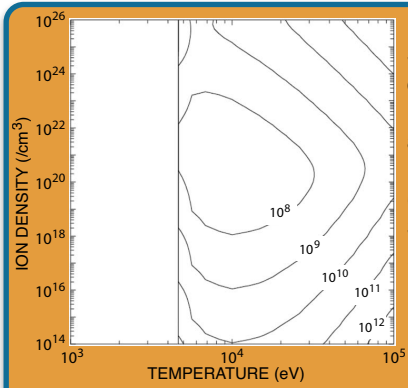
- Carbon-free, dispatchable power
- Virtually unlimited fuel
- No risk of meltdown

In the ALPHA program, we want to create more options for fusion energy.

…but they have to offer low-cost development pathways to be real options.

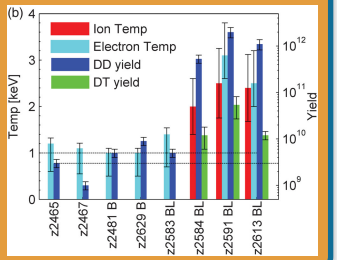
ALPHA seeks:

- New approaches to fusion based on low-cost technologies
- High shot rate for rapid learning
- All built to exploit physics of intermediate density regime



Scaling for power and energy requirements points to low-cost options at intermediate densities.

(ref. Lindemuth and Siemon, *Am. J. Phys. 2009*)



Early data from Sandia's MagLIF experiments lend support the case for intermediate densities.

(ref. Gomez et al., *PRL 2014*)

Success in the ALPHA program will create new options for fusion energy that can be compatible with private development.

ALPHA program goals

Intermediate density:

- Seeking approaches for 10^{18}-10^{23} cm^{-1} (at full compression)

Rapid progress: high shot rate

- Projects required to perform hundreds of shots in 3-year program
- Long term goal: Pulsed reactors with repetition rate ≥ 1 Hz

Low cost per shot:

- Long term goal: Low cost drivers (< $0.05/MJ) and targets (< 0.05 ¢/MJ)

More options:

- Nine teams selected – $30M (total) over 3 years
- Diverse set of approaches across intermediate density regime(s)

See the archived Funding Opportunity Announcement for ALPHA, No. DE-FOA-0001184, at arpa-e-foa.energy.gov for rationale and references

ALPHA portfolio of intermediate density approaches

Los Alamos NATIONAL LABORATORY

Plasma liner implosion by merging supersonic plasma jets

Helion Energy

Staged magnetic compression of field-reversed configuration plasmas.

UNIVERSITY of WASHINGTON

Shear-flow stabilized Z-pinch pushed to higher density and fusion conditions

BERKELEY LAB
Lawrence Berkeley National Laboratory

Scalable ion beam driver based on microelectromechanical systems (MEMS) technology

NumerEx

Piston-driven implosion of rotating liquid metal liner as fusion driver

SWARTHMORE

“Plasma rope” plumes as a potential magneto-inertial fusion target.

Sandia National Laboratories

Compression and heating of high energy density, magnetized plasmas at fusion relevant conditions

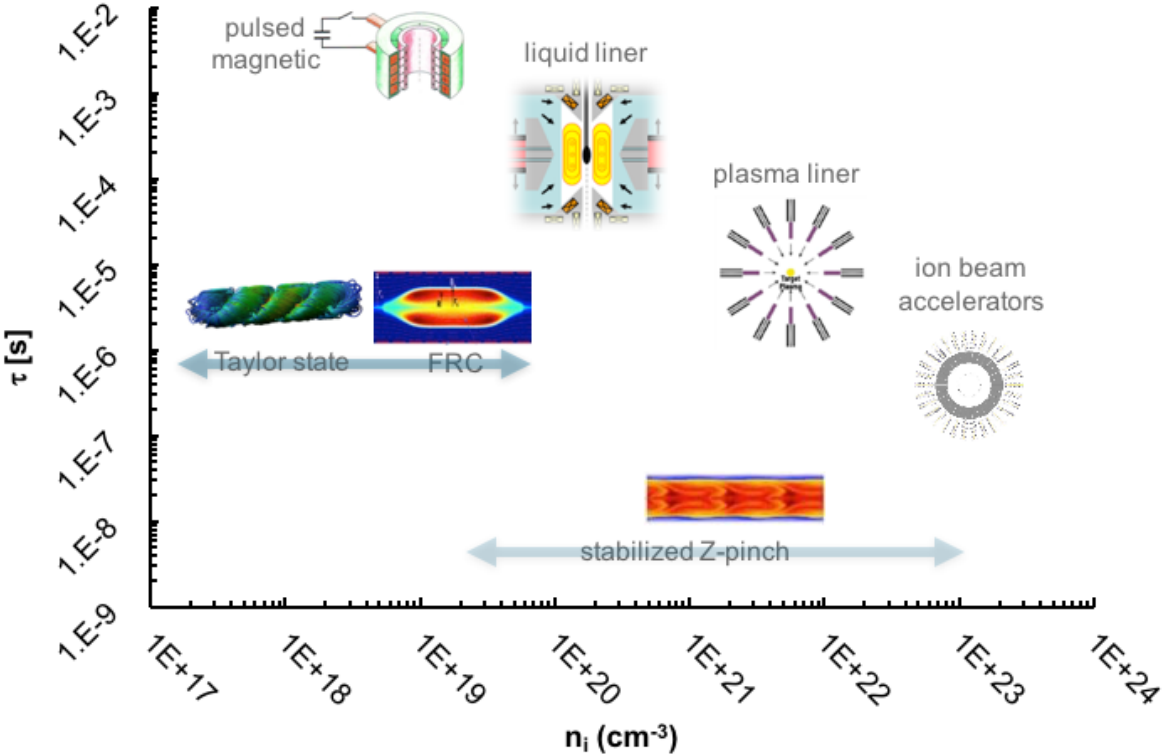
MIFTI
Clean Energy

Staged Z-pinch – a radially-imploding liner on a target plasma

CALIFORNIA INSTITUTE OF TECHNOLOGY
1891

Investigate collisions of plasma jets and targets to characterize fusion scaling laws

Breadth of ALPHA portfolio

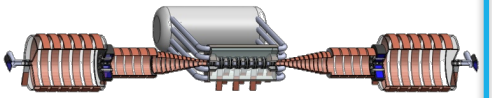


Integrated systems

Helion Energy

MSNW

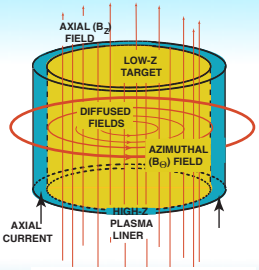
Coronado Consulting



Formation, acceleration, merging, and compression of field-reversed configuration (FRC) plasmas to fusion conditions. Staged magnetic compression and magnetic energy recovery offer rapid repetition rates.

MIFTi Clean Energy

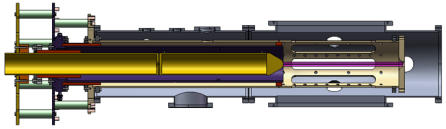
UCSD



Staged z-pinch (radially-imploding liner on a target plasma) offers stable, shock-driven implosion on inner surface (even with unstable outer surface). Magnetic-flux compression confines fusion-reaction products for efficient heating

UNIVERSITY of WASHINGTON

Lawrence Livermore National Laboratory



Shear-flow stabilized z-pinch pushed to high density and temperature. Simple geometry and operation—no field coils—for economical fusion with low-cost and high shot rate.

Success in ALPHA:

Demonstrate stability, scaling, and (ultimately) yield for reactor concept

MIF Drivers

Los Alamos NATIONAL LABORATORY

HYPERV TECHNOLOGIES CORP

THE UNIVERSITY of NEW MEXICO

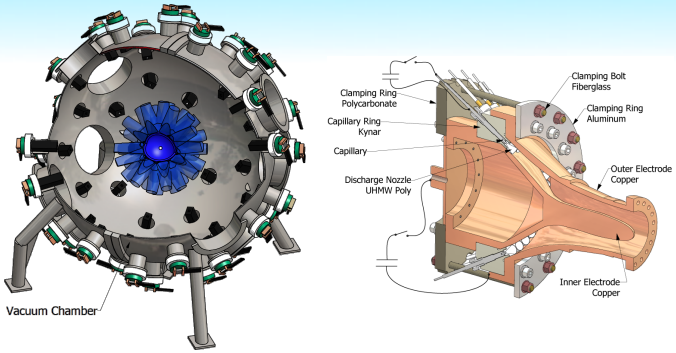
XTECH-X

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

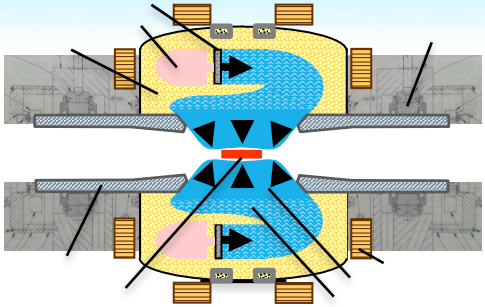
BROOKHAVEN NATIONAL LABORATORY

NumerEx

Creative Engineers, Inc.
UNITED STATES | CANADA | INTERNATIONAL



Merged plasma jets form plasma liners for high velocity implosion of an MIF target. Standoff drivers capable of high repetition rates and high efficiency.



Piston-driven implosion of rotation-stabilized liquid metal liner to compress plasma. High shot rate for development system and multipurpose liner/blanket/thermal medium for power reactor.

Success in ALPHA:

Demonstrate performance (v_{imp}, ram pressure, uniformity) and scaling for MIF reactor

Exploratory Concepts

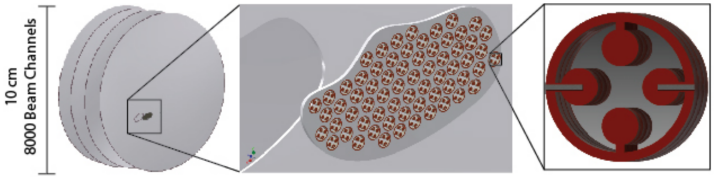
BERKELEY LAB

Cornell University

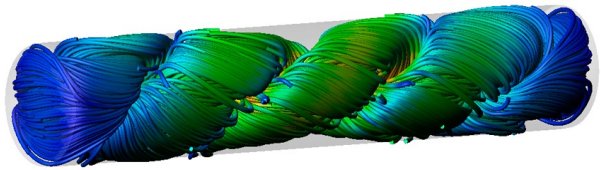
SWARTHMORE

BRYN MAWR COLLEGE

WOODRUFF • SCIENTIFIC



Ion beam driver based on a microelectromechanical systems (MEMS) multi-beamlet accelerator. Demonstrate high current density (10-100x SOA), high efficiency (20-50%) operation of scalable, low-cost technology.



Acceleration, stagnation, and merging of "plasma ropes" (Taylor states) to high density; determine stability limits and lifetime. Assess as long-lived plasma targets for MIF.

Success in ALPHA:

Proof-of-concept for new approaches to fusion drivers (LBNL) and targets (Swarthmore)

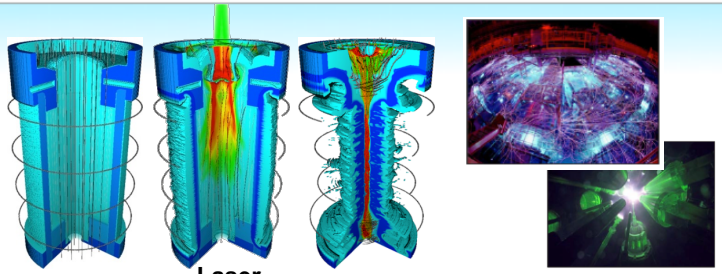
Underlying science of magneto-inertial fusion

Sandia National Laboratories

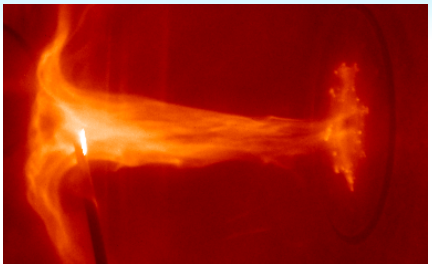
UR LLE

California Institute of Technology 1891

Los Alamos National Laboratory



Compression and heating of high energy density, magnetized plasmas at fusion relevant conditions. "Mini-MagLIF" at LLE enables high experimental throughput.



Collisions of plasma jets with targets in "reversed frame of reference" MIF analogue. Characterize dimensionality of adiabatic compression in MIF.

Success in ALPHA:

Rapid experimentation, benchmarking of codes for MIF concepts

ALPHA Year 1 Accomplishments

- Demonstrated plasma jets with repeatable ~2 mg/shot at ~10^{17}/cm^3 and >30 km/s. Three guns mounted and firing for merging experiments, and benchmarking codes for liner formation and dynamics.
- Completed detailed MACH2 analysis of liquid liner dynamics (Na or Li) and machine design for 1-2 km/s implosion (10 cm bore, 3000 RPM).
- Fielded first integrated laser-driven MagLIF experiments, initiate with 6 T and >11 atm, achieved ~2x increased yield over zero B-field implosions.
- Fielded integrated staged Z-pinch experiments (Ar/Kr annulus, ~10^{16}-10^{17} /cm^3; on D2 target, ~10^{17}-10^{18}/cm^3); achieved .
- Demonstrated three-stage RF acceleration of Ar-ion in MEMS stack (>2 kV acceleration in preliminary demo on 3x3 array), and MEMS ESQ focusing elements.
- Initiated conceptual fusion plant cost study with Bechtel National, Inc. (in collaboration with Woodruff Scientific)

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ENERGY

https://arpa-e.energy.gov