ARPA-E: Modeled after DARPA, focused on energy

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

**Means:**
- Identify and promote revolutionary advances in fundamental and applied sciences
- Translate scientific discoveries and cutting-edge inventions into technological innovations
- Accelerate transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty

Ensure U.S. Technological Lead & U.S. Economic and Energy Security
ALPHA seeks more options for fusion energy

Fusion Core ($BB$)

\[ n_i = \text{ion density (#/cm}^3) \]

- Higher B
- Smaller size
- Lower min. energy

- Magnetized target
- Slower implosion
- Lower min. power

ITER

NIF

n_i = ion density (#/cm^3)
ALPHA seeks more options for fusion energy

 ITER
 Higher B
 Smaller size
 Lower min. energy

 NIF
 Magnetized target
 Slower implosion
 Lower min. power

 $n_i = \text{ion density (#/cm}^3\text{)}$

 DIFFUSED
 HIGH-Z
 PLASMA
 LINER

 LOW-Z
 TARGET

 AZIMUTHAL (B $\Theta$)
 FIELD

 AXIAL (B $\mathcal{Z}$)
 FIELD

 AXIAL CURRENT

 pulsed magnet
 liquid liner
 plasma liner
 stabilized Z-pinch

 ARPA·E
 CHANGING WHAT’S POSSIBLE
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 $\geq 1$ 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 teams and approaches

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Progress on stabilized Z-pinches

Shear-stabilized Z-pinch
- Stability maintained up to high currents (~200 kA)
- Initial operations with D show neutron production

Staged Z-pinch
- Shock stabilized interface and D-D yields ~10^9 to 10^10 (in agreement w/ Mach2)
- Secondary D-T neutrons detected
Update on Plasma Liner for MIF

Plasma liner for MIF implosion formed by merging high-Z plasma jets

- Six jet merging experiments showed primary & secondary shock formation
- Initial rise in ion temperature followed by decrease as ions equilibrate with electrons
- Experimental results consistent with 2 temperature simulations.

Addresses a critical risk for plasma liner – high Mach number required for high-gain MIF
Applied Science of Magneto-Inertial Fusion

Compression of Taylor state as stable plasma target
- Data consistent with "Parallel" CGL (Chew, Goldberger and Low) EOS

Parallel CGL:
\[
\frac{\partial}{\partial t} \left( P \right)_{\parallel} + \nabla \cdot \left( n B^2 \right)_{\parallel} - \frac{1}{n^3} = 0
\]

Collisions of jet with gas for "reversed frame" MIF experiment
- Seek dimensionality of adiabatic compression.
- Scaling appears 3D

"Mini-MagLIF" at LLE enables high experimental throughput at fusion conditions.

- Demonstrated a nearly linear increase in yield in integrated MagLIF experiments on Omega with increasing applied magnetic field (as expected from simulations).
- Fielded improvements in laser pre-heat on Z
ALPHA Fusion Power Plant Conceptual Cost Study

Bechtel National, Woodruff Scientific, and Decysive Systems performed an initial capital cost study of 4 distinct fusion core approaches based upon a common 150 MW_e balance of plant

Key takeaways:
- Fusion core is significant, but not predominant, cost
- Uncertainty in neutronics and tritium systems remains high, but impact on plant cost is modest
- Cost of pulsed power systems matters
- Economics likely dictated by scale and balance of plant components