Lattice Confinement Fusion-Fast-Fission

Disruptive Technologies Briefing
Space Economy and Advanced Manufacturing Working Group
November 4, 2024
Washington, D.C.

L. P. Forsley[1]
CTO, Global Energy Corporation, Annandale, VA; San Diego, CA
PI, Lattice Confinement Fusion Fast-Fission Project, NASA GRC, Cleveland, OH

Dr. P. A. Mosier-Boss
Chief Scientist, Global Energy Corporation, San Diego, CA

Dr. T. L. Benyo
PI, Lattice Confinement Fusion Project, NASA GRC Cleveland, OH

1. lforsley@gechybrid.com, lawrence.p.forsley@nasa.gov

Outline

- **Lattice Confinement Fusion (LCF)**
  - Published 2020, *Physical Review C* [1,2]
  - Patented and Commercialized 2024, Astral Systems
    - LCF in compact neutron generator 50x increase in neutron flux, 99% from LCF
    - Produce medical radioisotopes
- **LCF Fast-Fission Hybrid Reaction**
  - *No Enriched Uranium*
  - Demonstrated with US Navy and GEC
  - Modeling and Scaling under NIAC and NSF funding
- **Application**
  - Deep space
    - Power: Icy worlds
    - Propulsion: Nuclear Electric Propulsion
    - Planetary Surface Power: Lunar and Mars
  - Terrestrial
    - DoD Operational Energy
    - Onsite power for Data Centers

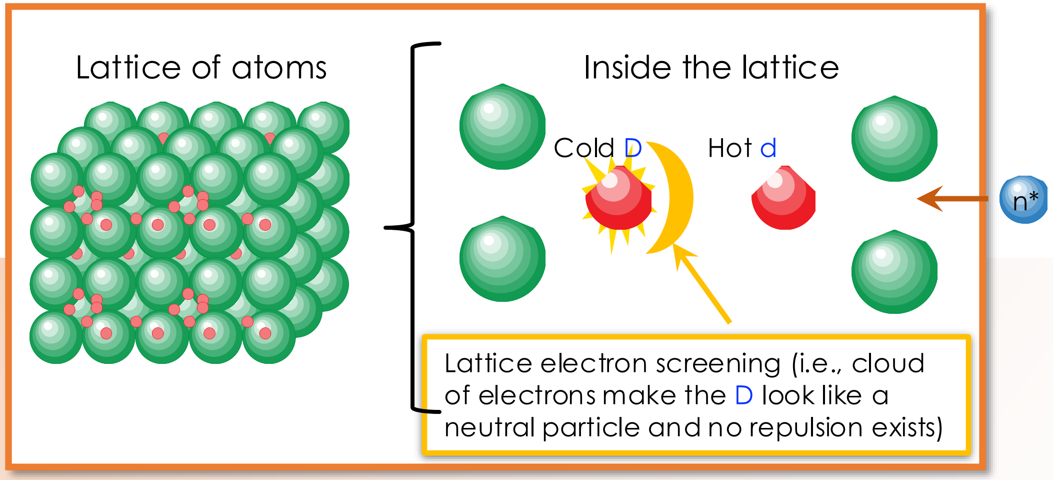
1. V. Pines, *et al*, “Nuclear Fusion Reactions in Deuterated Metals”, *Phys Rev C*, **101**, (20Apr2020) 044609.
2. B. M. Steinetz, *et al*, “Novel Nuclear Reactions Observed in Bremsstrahlung-Irradiated Deuterated Metals”, *Phys Rev C*, **101**, (20Apr2020) 044610.

Lattice Confinement Fusion

Lattice Confinement Fusion (LCF)
How it Works

National Aeronautics and Space Administration

- Traditional fusion: Heats plasma 10x hotter than center of sun – *hard to control*
- LCF addresses the pressure, temperature, and containment challenges with fusion
  - Heats up **very few** atoms at a time
  - Approaches solar fuel density
  - Lattice provides containment and screening

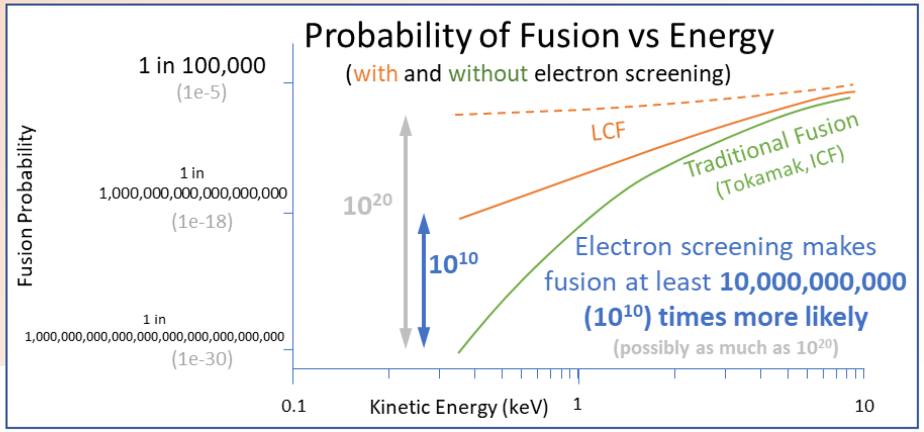


Technical Details Simplified

Part A: Electron Screening
(increases fusion probability)

Part B: High Fuel Density
(billion times more dense than magnetic fusion)

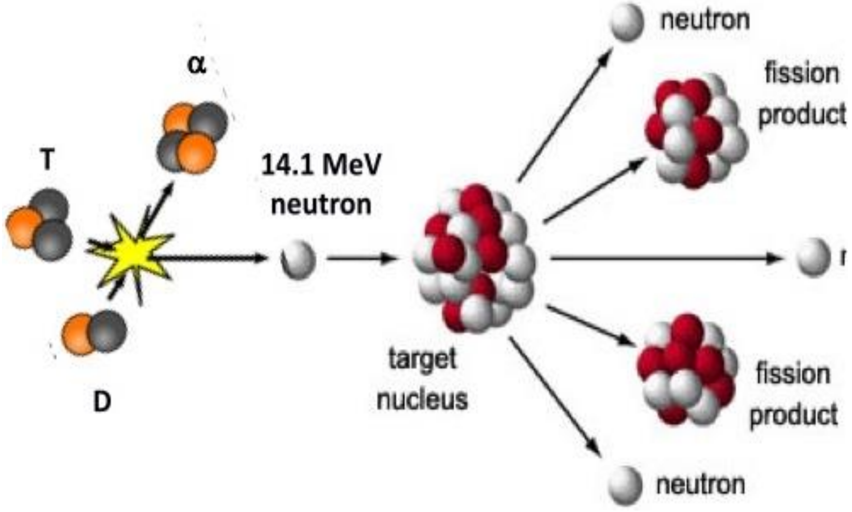
A + B (+ trigger) **= Viable Fusion**



Lattice Confinement Fusion

LCF Hybrid Fusion-Fast Fission

- **Takes advantage of both processes**
  - Fusion reactions provide the neutrons to fission non-fissile material, natural uranium, thorium, DU
  - *No enriched uranium: No LEU, HALEU or HEU*
  - Require ~2 MeV neutrons to fission natural thorium uranium and spent nuclear fuel rods
  - Fusion reactions provide up to 14.1 MeV neutrons



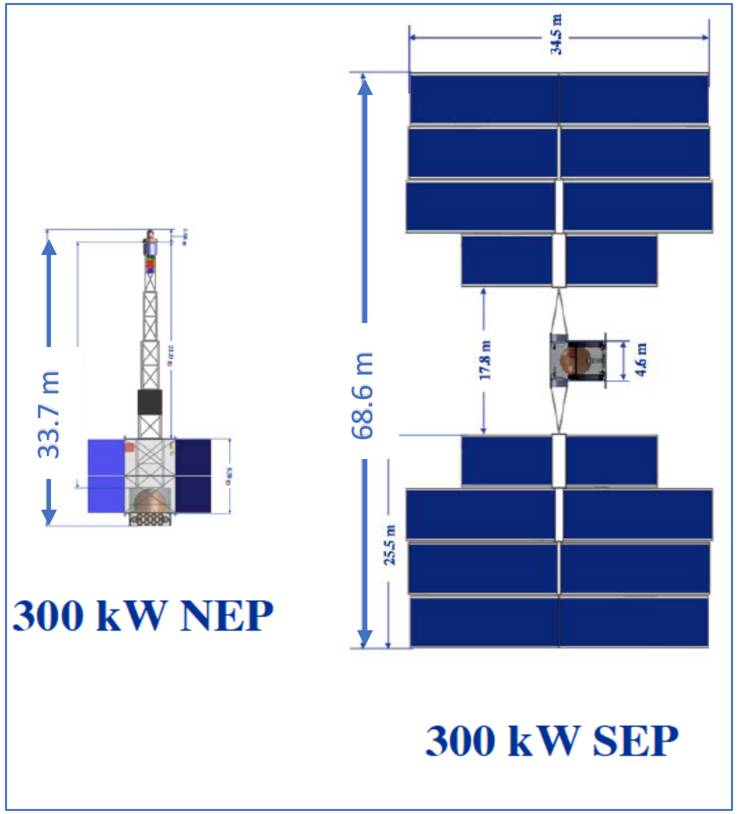
Fusion Reaction	MeV	Occurrence	useful particle energy (MeV)
D(d,n)^{3}He	4.00	primary ≈ 50%	n=2.45
D(d,p)T	3.25	primary ≈ 50%	p=3.00
D(^{3}He,p)α	18.30	secondary	p=15.00
D(t,n)α	17.60	secondary	n=14.10
T(t,α)2n	11.30	low probability	n=1 to 9
^{3}He(^{3}He,α)2p	12.86	low probability	p=1 to 10
Fission Reaction	**MeV**	**Occurrence**	**useful particle/energy (MeV)**
^{232}Th(n,γ)f	200	high probability	n=1 to 9
^{232}Th(p,γ)f	200	some probability	p=1 to 10
^{238}U(n,γ)f	200	high probability	n=1 to 9
^{238}U(p,γ)f	200	some probability	p=1 to 10

GEC patented technology

US Patent 8,419,919, System and Method for Generating Particles:
fast neutrons and charged particles

Application

- **Deep space**
  - Power
    - Melt through 45 km of Ice shells of Icy worlds
  - Nuclear Electric Propulsion
  - Planetary Surface Power
    - 10 – 100 kWe Lunar and Martian Power
  - *Untended operation 5+ years*
- **Terrestrial**
  - DoD Operational Energy < 1 MWe
  - Small Modular Reactors: Data Centers > 1 MWe
- **Going Forward**
  - NIAC LANL MCNP Modeling finished
  - NSF Supported Scaling on-going



Nuclear Electric Propulsion (NEP) heat dissipation panels as compared to Solar Electric Propulsion (SEP)[1] solar panels.
Mass, volume, lifetime matter!

If It's safe enough to launch from Florida, its safe enough to use in Florida!™

[1] L. Mason, "High Power NEP Power Concepts", *NASA GRC*, (2017) where the 300 kW NEP was for JIMO/Project Prometheus.

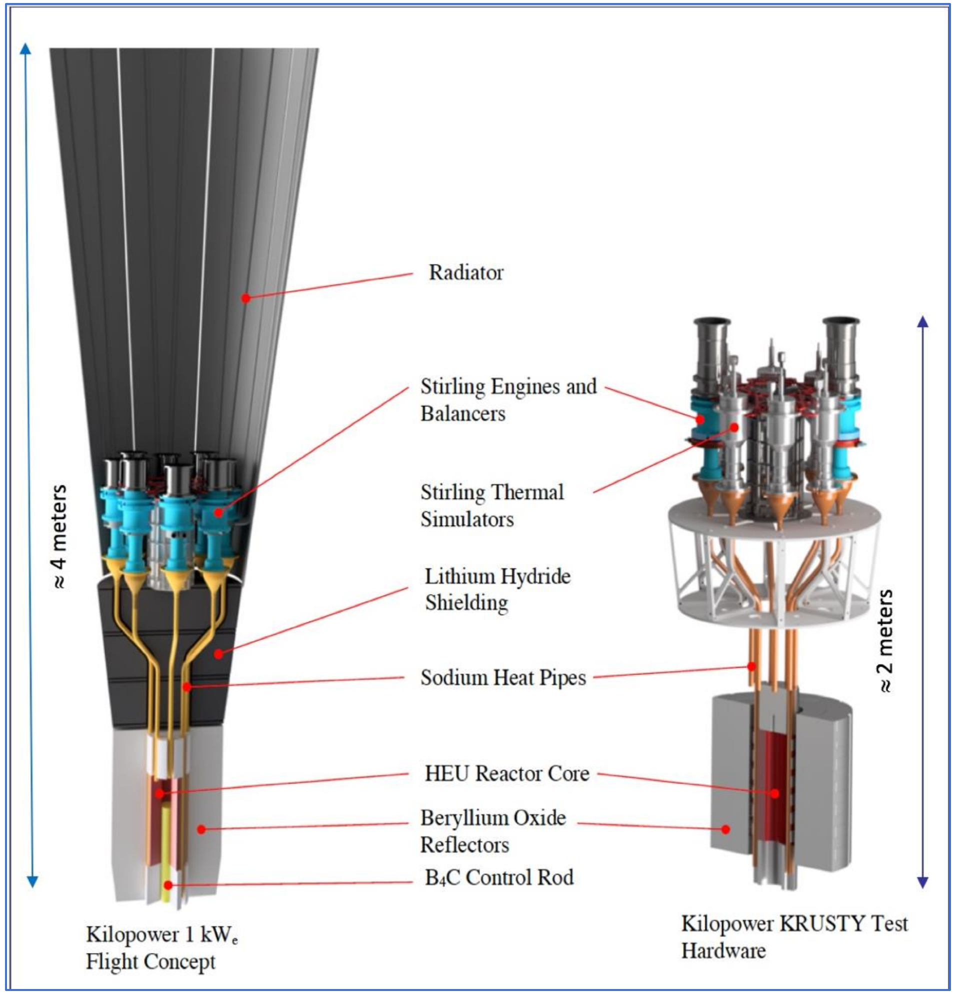
Backup Slides

Comparison

Comparing tests of unoptimized LCF Hybrid to Krusty

- LCF Hybrid and the Kilopower KRUSTY are fast fission reactors.
- Hybrid: 38 mg of 99.3 % ^{238}U (0.7% ^{235}U), 33.5 hours (arbitrary)
- KRUSTY: 28 kg of 93.0 % enriched ^{235}U (7% ^{238}U), 28 hours (arbitrary)
- *One thermal watt requires 3×10^{10} fissions/s*.
- KRUSTY : 9×10^{10} fissions/cm^3/s. (given 3 W/cm^3)
- Hybrid: 10^4 - 10^6 n/s from a volume of 3×10^{-5} cm^3 (38 % Krusty power density)

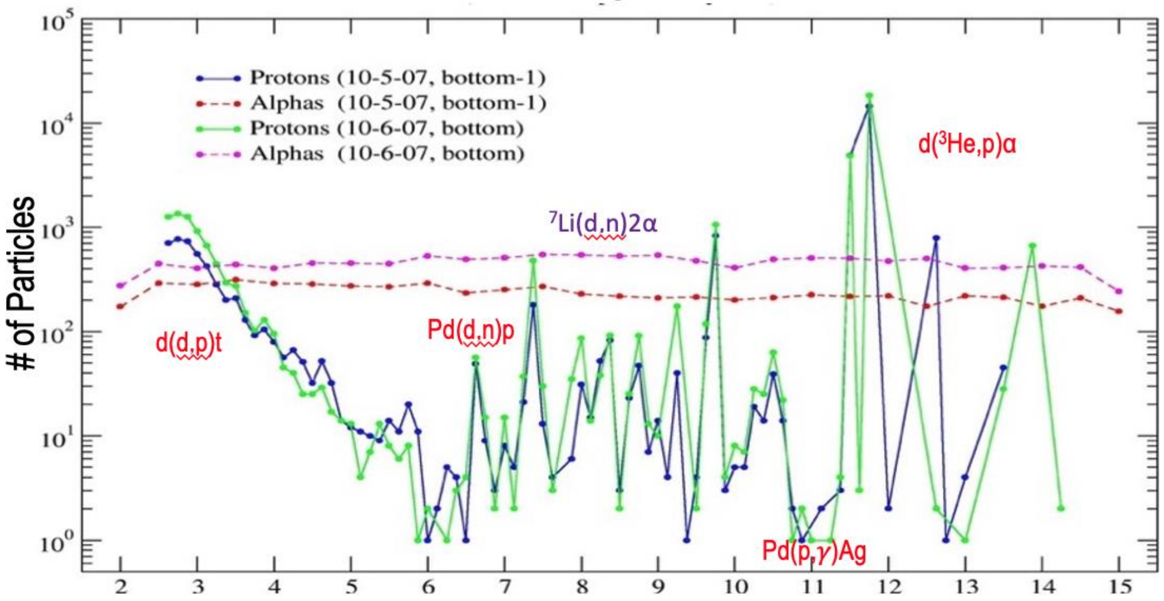
LCF would only replace the Kilopower enriched ^{235}U core, controls and shielding while retaining power conversion, heat pipe and thermal radiator.



Kilopower Flight Concept

LCF Nuclear Reaction
Energetic Particle Cascade Spectroscopy

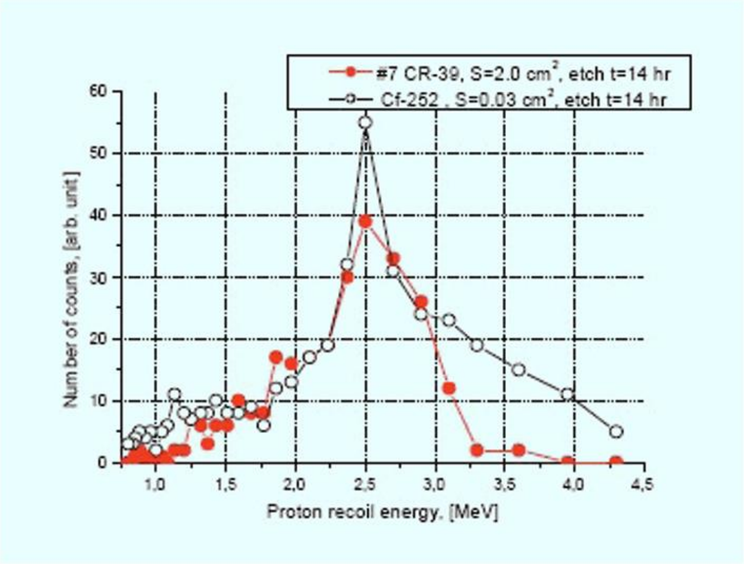
Protons and Alpha Particles



Particle energy in MeV

NASA JSC Linear Energy Transfer Analysis (CR-39) from two experiments[1,2]: e.g. ^{7}Li(d,n)2α 3-body nuclear reaction and neutron induced recoils.

Neutron recoils: 1 - 4.5 MeV



Recoil Particle energy in MeV

SRI, (Menlo Park, CA), replication of SPAWAR patented protocol analyzed at Lebedev Institute (Moscow, Russia)[3]
Grey: ^{252}Cf neutron source, Red: PdD/Ag

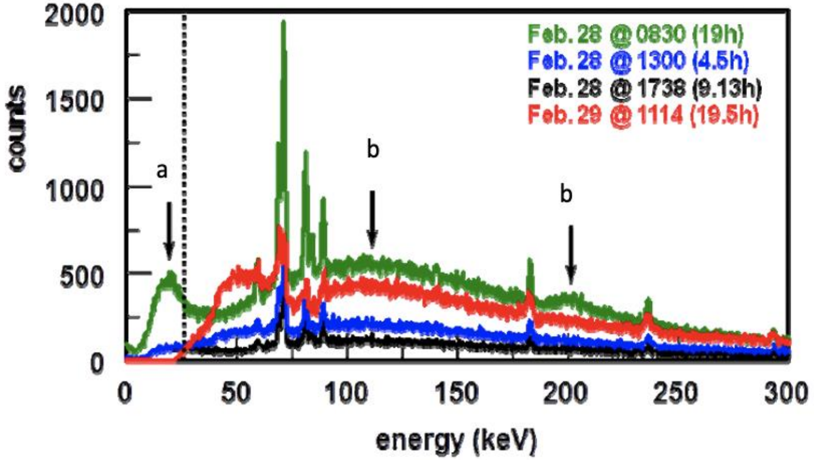
[1] P.A. Mosier-Boss, F.E. Gordon, L.P. Forsley, D. Zhou," Detection of high energy particles using CR-39 detectors part 1: Results of microscopic examination, scanning, and LET analysis", *International Journal of Hydrogen Energy* **42**, 1 (2017) pp 416-428.
[2] US Patent #8,419,919, "System and Method for Generating for Particles", (2013).
[3] A.G. Lipson, A.S. Roussetski, E.I. Saunin, F. Tanzella, B. Earle and M. McKubre, "Analysis of the CR-39 detectors from SRI's SPAWAR/Galileo type electrolysis experiments #7 and #5. Signature of possible neutron emission", 8th Int. Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals, (2007).

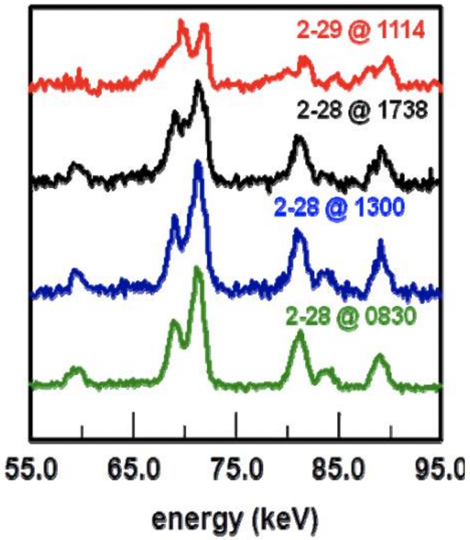
Proton's and alpha's specie and energy measured using NASA JSC Linear Energy Transfer Analysis Code.
No uranium or thorium were used.

Lattice Confinement Fusion

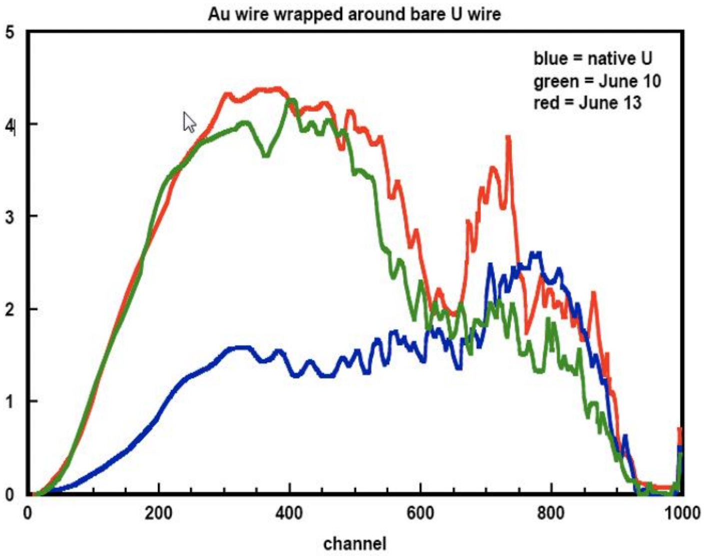
LCF Fast-Fission Hybrid Reactions (deuterated U) Gamma, Alpha and Beta Spectroscopy

HPGe γ Spectroscopy





Liquid Scintillator α, β spectroscopy



[a]Neutron capture within HPGe getter resulting in internal β induced bremstrahlung and decays, below the HPGe crystal Al window energy cut-off.

[b]Rising baseline due to neutron elastic scattering off Ge atoms.

Close-up up of growing neutron damage caused by induced Frankel Defect holes. (sample time corrected)

Blue: natural U decay daughters
Green: end of run, *fission product β decay*
Red: three days later, *activated α decay* has grown in

Fission products and activation

Fast Neutron production rate estimated at 10^6 n/second

[1.] Boss, Forsley and McDaniel, "INVESTIGATION OF NANO-NUCLEAR REACTIONS IN CONDENSED MATTER - FINAL REPORT", *DTRA,* (2016).