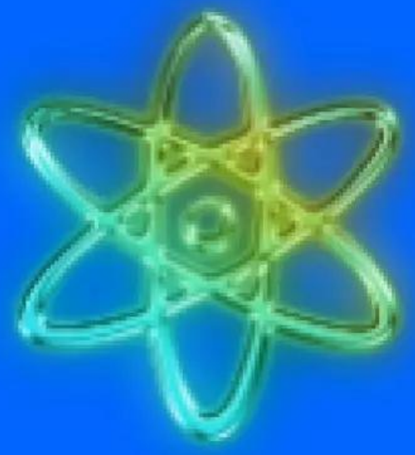
Ultralow energy neutron reactions (LENRs)

Disruptive new source of safe, radiation-free nuclear energy

LENR experiment conducted independently in 2017 by The Aerospace Corporation (non-profit that operates FFRDC) successfully repeated Japanese NEDO project excess heat results

AEROSPACE

The Aerospace Corporation reported its 2017 experimental data on June 5, 2018 at ICCF-21 conference in Ft. Collins, CO



Lewis Larsen

President and CEO

Lattice Energy LLC

June 6, 2018

Contact: 1-312-861-0115 Chicago, Illinois USA
lewisglarsen@gmail.com

The Aerospace Corporation - HQ El Segundo, California

Nonprofit company that operates U.S. government-funded R&D center

3,600 employees - its main customers are U.S. Air Force and NRO (spy satellites)

"The Aerospace Corporation is a California nonprofit corporation that operates a federally funded research and development center (FFRDC) headquartered in El Segundo, California. The corporation provides technical guidance and advice on all aspects of space missions to military, civil, and commercial customers. As the FFRDC for national-security space, Aerospace works closely with organizations such as the United States Air Force Space and Missile Systems Center (SMC) and the National Reconnaissance Office (NRO) to provide 'objective technical analyses and assessments for space programs that serve the national interest'. Although SMC and NRO are the primary customers, Aerospace also performs work for civil agencies as well as international organizations and governments in the national interest."

Source: Wikipedia

SPACE WARFIGHTING:

DEFENDING THE HIGH GROUND

“To end up on the winning side of a space conflict today, the United States needs new space systems and must change how it acquires and operates space systems. The Aerospace Corporation is helping the Air Force, government, and intelligence community plan a way forward --- one in which space systems are operated as an enterprise that can deliver integrated, multidomain (space, air, ground, and cyber) combat effects.”

SHAPING THE FUTURE 2017

THE AEROSPACE CORPORATION

Future LENR power and propulsion systems for the military

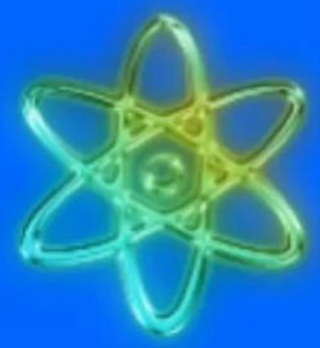
Ultralow energy neutron reactions (LENRs)

Disruptive new source of safe, radiation-free nuclear energy

LENRs expand use of nuclear power & propulsion into huge range of land vehicles, aircraft, watercraft, and spacecraft

Scales downward from fission reactors used in carriers and subs

Enormous energy densities of LENR-based power & propulsion technology could confer decisive combat systems advantages on near-future battlefields



Lewis Larsen

President and CEO

Lattice Energy LLC

May 24, 2018

Contact: 1-312-861-0115 Chicago, Illinois USA
lewisglarsen@gmail.com

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenrs-are-revolutionary-disruptive-energy-technology-for-future-military-power-and-propulsion-applications-may-24-2018

LENR technology's present global state of play is at TRL-4

Organizations involved in NEDO LENR device fabrication and test project

NEDO New Energy and Industrial Technology Development Organization

Combining the efforts of industry, government and academia and leveraging established international research networks. NEDO is committed to contributing to the resolution of energy and global environmental problems and enhancing Japan's industrial competitiveness.

NEDO

Technova Inc.

Mitsubishi H.I.: very deep experience in U^{235} nuclear fission reactor technology

Also designed and produces XASM-3 supersonic ramjet anti-ship missile

MITSUBISHI

TOYOTA

NISSAN

Toyota: world's 3rd largest automobile manufacturer; #1 in hybrid e-vehicles

Also doing 3G R&D in humanoid robots: latest is T-HR3 (like avatar of a human)

TOHOKU UNIVERSITY

NAGOYA UNIVERSITY

KOBE UNIVERSITY

KYUSHU UNIVERSITY

http://www.nedo.go.jp/english/

"Investigation of the Nickel-Hydrogen anomalous heat effect"

Beiting's work repeated Japan NEDO project's LENR excess heat results

Dr. Edward J. Beiting
Physicist and Senior Scientist (propulsion) at The Aerospace Corporation
https://www.researchgate.net/scientific-contributions/81491589_Edward_J_Beiting

https://www.dropbox.com/sh/sp71necll4mfv2w/AABLXuUL0v3NrkY7BPYPKDA_a?dl=0&preview=Beiting-Edward-1.pdf

"Experimental work was undertaken at The Aerospace Corporation to reproduce a specific observation of the gas-phase Anomalous Heat Effect (aka LENR) [1]. This task required the production of a quantity of heat energy by a mass of material so small that the origin of the energy cannot be attributable to a chemical process. The goal is to enhance its credibility by reproducing results first demonstrated in Japan and later reproduced in the U.S. by a solitary investigator. The technique heated nanometer-sized Ni:Pd particles (20:1 molar ratio) embedded in micron-sized particles of an inert refractory of ZrO_2. It was not within the purview of this work to investigate the physical origin of the AHE effect or speculate on its source."

Source: conference abstract (public pdf copy available for download at URL on dropbox.com)

Reference: [1] E. Beiting, "Investigation of the nickel-hydrogen anomalous heat effect" Aerospace Report No. ATR-2017-01760, The Aerospace Corporation, El Segundo CA, USA, May 15, 2017

"Investigation of the Nickel-Hydrogen anomalous heat effect"

Materials: 20 gms Ni:Pd nanoparticles embedded in μ-sized ZrO_2 particles

"An apparatus was built that comprised identical test and a reference heated cells. These thermally isolated cells each contained two thermocouples and a 10 cm^3 volume of ZrO_2NiPd particles [nanometer-sized Ni:Pd particles in 20:1 molar ratio embedded in micron-sized particles of an inert refractory of ZrO_2]."

"Calibration functions to infer thermal power from temperature were created by electrically heating the filled cells with known powers when they were either evacuated or pressurized with 1 bar of N_2. During the experimental trial, the test cell was pressurized with hydrogen and the control cell was pressurized with nitrogen."

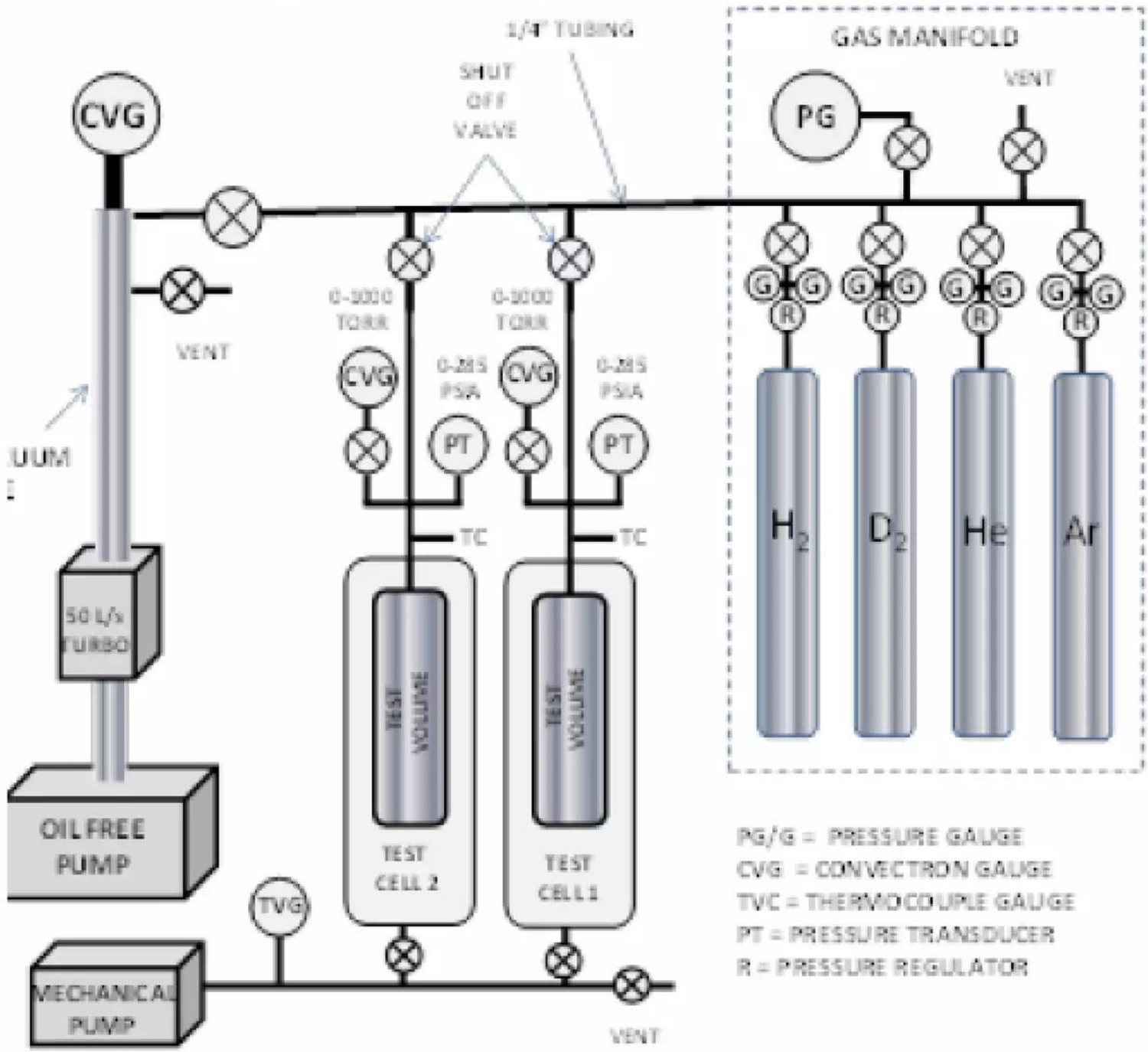
Source: conference abstract (public pdf copy available for download at URL on dropbox.com)

Reference: [1] E. Beiting, "Investigation of the nickel-hydrogen anomalous heat effect" Aerospace Report No. ATR-2017-01760, The Aerospace Corporation, El Segundo CA, USA, May 15, 2017

“Investigation of the Nickel-Hydrogen anomalous heat effect”

Figure 1: Apparatus used in Aerospace Corporation’s LENR experiments

Figure 1. AHE gas test cell system



Source: conference abstract

"Investigation of the Nickel-Hydrogen anomalous heat effect"

Over 40 days "test cell registered 7.5% > power (~1 Watt) vs. input power

"After conditioning the cells, both were heated to near 300°C for a period of 1000 hours (40 days). During this period, the test cell registered 7.5% more power (approximately 1 W) than the input power. The control cell measured approximately 0.05 W of excess power. The error in the excess power measurement was ± 0.05 W."

"Time-integrating the excess power to obtain an excess energy and normalizing to the 20 gram mass of the ZrO_2NiPd sample yields a specific energy of 173 MJ/kg. Assuming that the active material is the 5.44 g of Ni+Pd yields a specific energy of 635 MJ/kg. For comparison, the highest specific energy of a hydrocarbon fuel (methane) is 55.5 MJ/kg. The highest chemical specific energy listed [see Energy Density in Wikipedia] is 142 MJ/kg for hydrogen compressed to 700 bar. Based on these results, it is unlikely that the source of heat energy was chemical in origin."

Source: conference abstract (public pdf copy available for download at URL on dropbox.com)

Reference: [1] E. Beiting, "Investigation of the nickel-hydrogen anomalous heat effect" Aerospace Report No. ATR-2017-01760, The Aerospace Corporation, El Segundo CA, USA, May 15, 2017

"Investigation of the Nickel-Hydrogen anomalous heat effect"

Comments about Beiting's 2017 experimental results reported at ICCF-21

- Beiting generally tried to follow Japanese NEDO project's experimental protocols, including using published information about nanoparticle fabrication techniques, same ZrO_2/Ni/Pd material composition, and use of pure H_2/D_2. Also used nearly same operating temperatures & pressures for triggering. Reaction vessels (cells) were not identical to Japanese project; also used different method for measuring excess power produced by LENRs. Beiting reportedly used K-type thermocouples in thermally isolated reaction cells whereas NEDO project used flow calorimetry. Error in Beiting's measurements of excess power was estimated to be ± 0.05 W

- At ICCF-21 Beiting reported: 20 gram sample of nanoparticulate ZrO_2/Ni/Pd with Ni:Pd in 20:1 molar ratio; H_2 was pressurized to 1 bar; then heated to an operating temperature of 300° C for 40 days. Over that period, sample's test cell produced 7.5% more excess power (~1 Watt) versus Nitrogen-pressurized control cell which produced only 0.05 Watts of excess power. Assuming active material is 5.44 gms of Ni+Pd present in test sample, its calculated specific energy is 635 MJ/kg. This very high value for specific energy cannot be explained by any chemical process

- Japanese NEDO Ni+Pd nanoparticulate samples each averaged ~100 - 130 grams. Had Beiting's active material been this heavy, it may have produced over 10 Watts

- Conclusion: for all practical purposes, experiment conducted by The Aerospace Corporation effectively repeated results reported by Japan's NEDO LENR project

NEDO's recent LENR results: key technological advancement

LENR devices created Watts of excess heat with 70 - 80% reproducibility

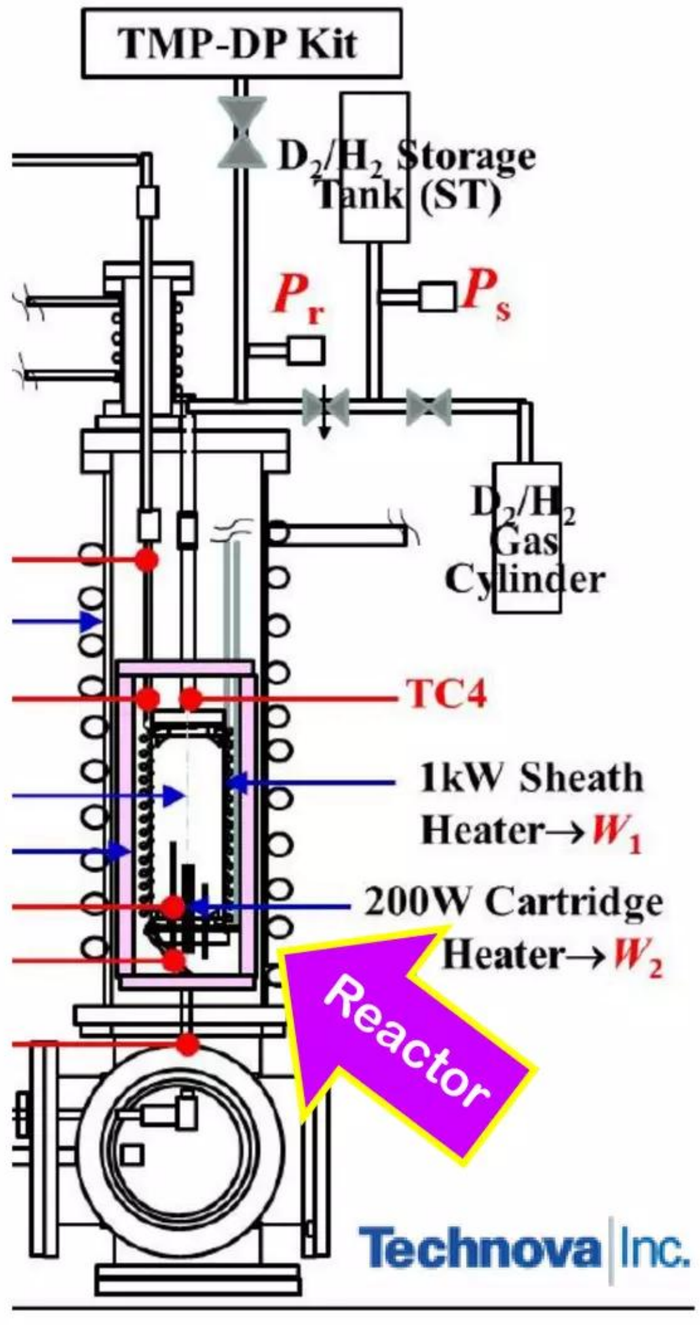
- NEDO LENR project's Pd/Ni/Zr devices' excess heat performance exceeded 99% of all results produced by LENR Pd/Pt electrochemical cells that probably comprised 70 - 80% of experimental systems utilized in LENR field since 1989
- Excess heat performance of NEDO project LENR devices also vastly exceeded planar thin-film multilayer Pd/CaO metal-oxide heterostructures through which H_2 or D_2 gas was permeated with modest pressure gradients; Mitsubishi Heavy Industries (MHI) developed this experimental method in 2001. Was excellent for demonstration of LENR transmutation products found in microscopic surface domains with SIMS or XPS analysis; input energy with MHI permeation method too low to make enough ULE neutrons to create readily measurable excess heat
- NEDO project's nanocomposite LENR devices achieved best-ever performance in history of field since 1989 with respect to average peak Watts of measured excess heat production and % of experiments that successfully created heat
- Technology readiness-wise, NEDO LENR project's recent technical progress with excess heat production and reproducibility is a watershed development. Technology readiness level of LENRs is arguably now early TRL-4 (European Commission definitions); completion of stage TRL-9 represents successful introduction of commercial consumer products. Achieving TRL-4 is important milestone in development of LENRs into useful commercial energy technology

NEDO project utilized standardized apparatus and protocols

Excellent calorimetry accurately measures excess heat production in RC

Generic overview of experimental run after LENR device nanomaterials fabrication

1. Non-destructively characterize LENR device materials
2. Place LENR materials + filler in reaction chamber (RC)
3. Open valve: admit either 99+%-pure D_2 or H_2 gas into reaction chamber at ~1 atm pressure and room temp; then close valve (RC is sealed); measure excess heat production via calorimetry (is negligible @ room temp)
4. Use external heating to warm-up reaction chamber to working temperatures of 150 - 450º C (avg. 200 - 300)
5. Conduct experimental run for planned period of time: continuously measure excess heat production inside RC via calorimetry (excess heat ≈ measured total thermal output from RC minus total thermal input into RC) for remaining duration of given experimental run
6. Stop experiment; remove all sample materials from RC
7. Post-experiment: analyze LENR device nanomaterials

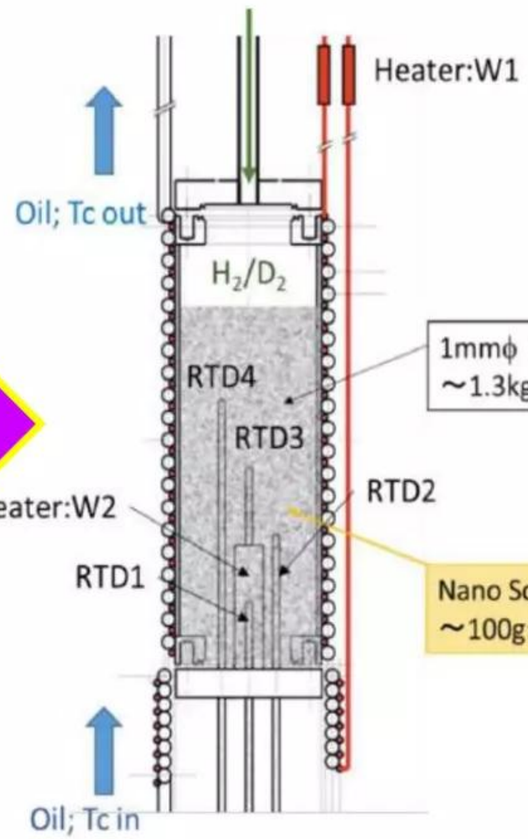


Overview of NEDO project LENR reactor in 2017 experiments

Nanocomposite LENR target fuel materials and filler in reaction chamber

~100⁺ grams of Ni/Pd nanoparticles mixed with 1,300 gms. 1 mm Zirconia filler beads

Reaction Chamber (500 cc) and filler + sample



Reactor

1mmϕ Zirconia Beads; ~1.3kg

1mmϕ beads

~1,300g

Nano Scale Sample; ~100g: PNZ, CNZ, etc...

CNZ6s sample

~100g

Technova Seminar 2018/3/2 Technova Inc. Technova Seminar 2018/3/2 31

NEDO sample PNZ7k Pd_1/Ni_7 nanoparticle loading with D(d^+)

D(H)/Metal-atom ratio > 0.80 for many-body d^+ islands to form on surface

Widom-Larsen theory: LENR active sites form spontaneously on nanoparticle surfaces

Sample	Mass (g)	Molar ratio				ZrO_2 filler mass (g)
		Ni	Pd	Zr	O	
PNZ7k	99.8	**0.306**	**0.044**	**0.650**	0.274	1531
calcined at 450°C·60h		7 : 1				

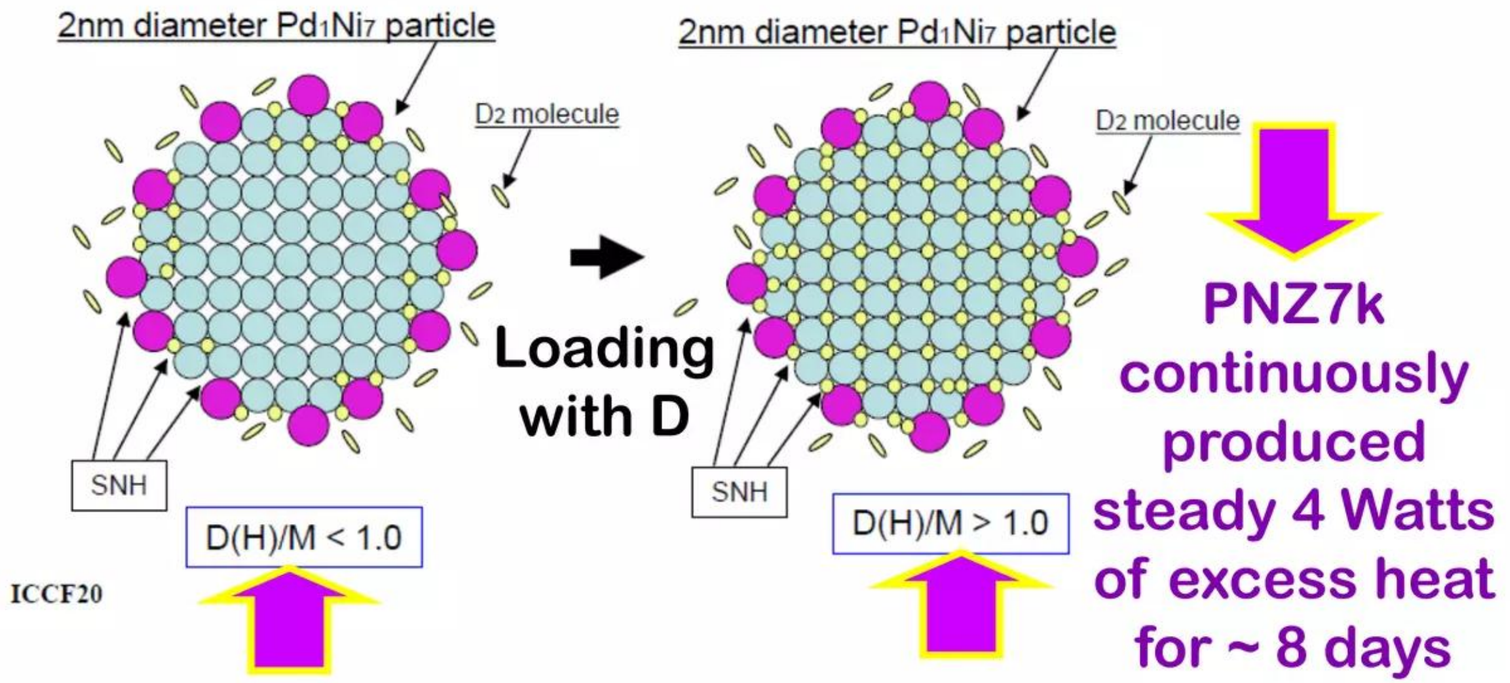
4 Watts

4 Watts

SNHs are prepared by O-reduction to start D(H) absorption (left)
And D(H)/M loading ratio exceeds 1.0 level (right)

D(H)-atom
Ni-atom; r_0 = 0.138 nm
Pd-atom; r_0 =0.152 nm (or Cu)

D(H)-atom
Ni-atom; r_0 = 0.138 nm
Pd-atom; r_0 =0.152 nm (or Cu)



ICCF20

Technova Seminar 2018/3/2 Technova Inc. Technova Seminar 2018/3/2 51

Further info about Japanese NEDO project's reported results

Purplish hyperlinks below are 'live' as well as in SlideShare PowerPoints

"Commercialization of radiation-free LENRs for power generation could occur with surprising speed: after stagnating at TRL-3 for 10+ years Japanese industry-academic consortium including Mitsubishi Heavy Industries, Toyota, and Nissan Motor Company, achieved TRL-4 in 2.5 years and spent less than US$54 million"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-revolutionary-lenrs-for-power-generation-accelerating-development-path-from-present-trl4-to-trl9-april-9-2018

"Japan's NEDO LENR device fabrication and testing project achieved key technological milestones – more data released in Technova seminar on March 2"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-march-2-technova-seminar-in-tokyo-released-more-info-re-nedo-lenr-device-project-march-12-2018

"Small, primitive nanocomposite LENR devices fabricated in NEDO project produced enough cumulative excess heat to boil cup of tea for up to 45 days"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-industryacademiagovernment-project-nanocomposite-lenr-devices-produce-enough-heat-to-boil-cup-of-tea-feb-7-2018

"Japan's NEDO industry-academia-government R&D program's recent experimental results technically validated potential for LENRs to become major future energy source"

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-nedo-lenr-project-reported-reasonably-reproducible-wattlevel-excess-heat-production-feb-4-2018

LENRs are an incredibly interdisciplinary area of science

Resisted understanding until Widom-Larsen put all the pieces together

Many-body collective quantum effects in LENR active sites enable the 'impossible'

Scientists observed LENRs for 100 years but didn't connect anomalies to nuclear processes

Many-body collective Q-M effects

Quantum electrodynamics (QED)

Chemical/enzymatic catalysis

Modern quantum mechanics

Condensed matter physics

Classical electrodynamics

Plasmonics & photonics

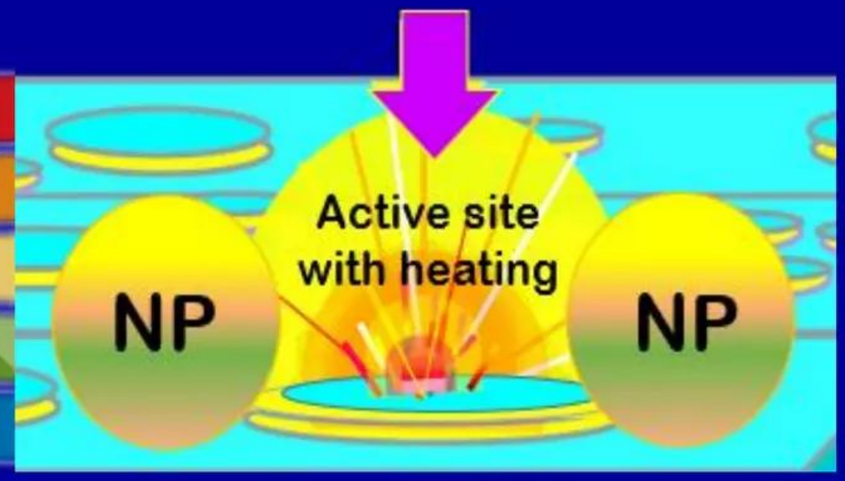
Modern nuclear physics

Select nanotechnology

Surface physics (H,D)

Dusty plasma physics

Many disciplines are needed to fully understand key physics and operation of microscopic LENR active sites



NP = nanoparticle

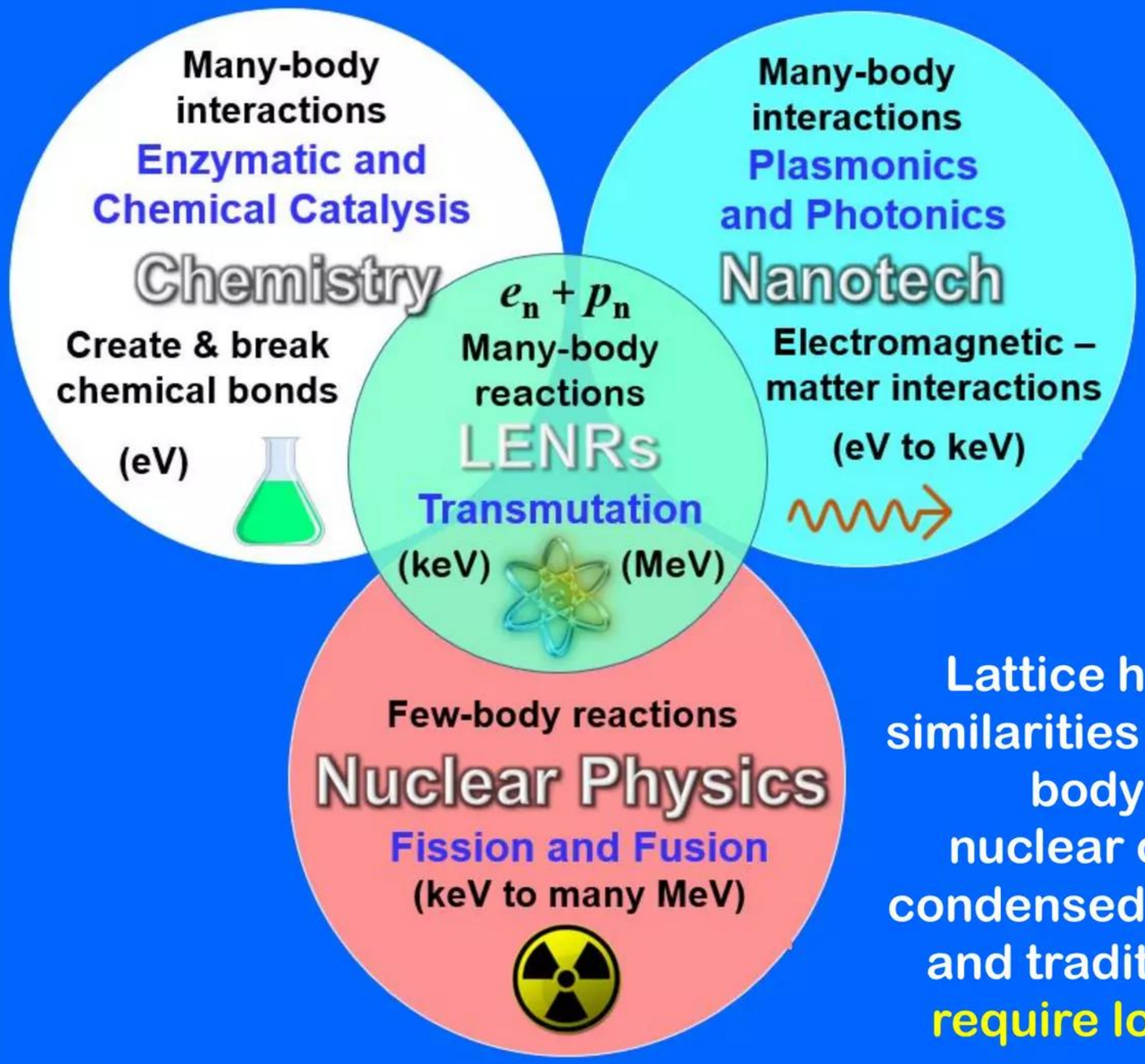
Micron (μm) to nanometer (nm) length-scales

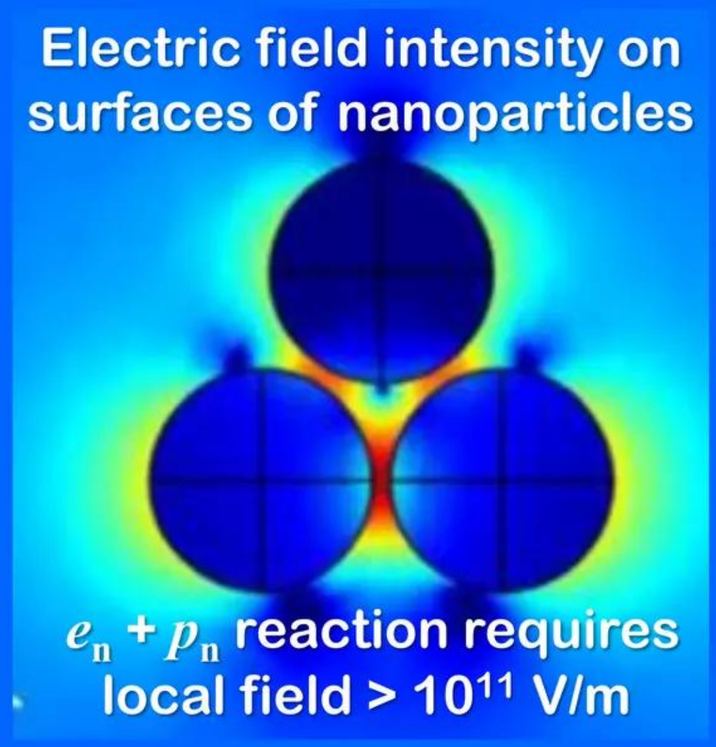
LENR active sites, as a key functional unit, are analogous to transistors in microchips

LENRs are not as exotic a technology as many might assume

Widom-Larsen theory: LENR physics, nanotech & chemistry interrelated

Leverage W-L theory & nanotech know-how to accelerate LENR development





Lattice has discovered deep causal similarities between what enables many-body collective electroweak nuclear catalysis ($e_n + p_n$ reaction in condensed matter), enzymatic catalysis, and traditional chemical catalysis: all require local electric fields ≥ 10^9 V/m

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-japanese-confirm-lattice-hypotheses-re-importance-of-adsorbed-protons-and-high-local-electric-fields-in-chemical-catalysis-june-27-2017

Electroweak neutron production in Widom-Larsen theory

Protons or deuterons can react directly with electrons to make neutrons

Input energy required to trigger many-body $e_n + p_n$ reactions in LENR active sites

Input energy boosts electric fields >10^{11} V/m

Collective many-body quantum effects: many *sp* electrons each transfer little bits of energy to a much smaller number of *sp* electrons also bathed in same nuclear-strength local electric field > 10^{11} V/m

Heavy-mass e^{-}* electrons react directly with protons

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) ⟶ neutron and neutrino

Input energy

$$\text{Energy}_{\text{E-field}} + e^-_{\text{n}\,sp} \rightarrow e^{-*}_{\text{n}\,sp} + p^+_{\text{n}} \rightarrow n^0_{\text{ule}} + \nu_e$$

ν_e neutrinos: ghostly unreactive particles that fly-off into space; n^0 neutrons capture on nearby atoms

Induces safe hard-radiation-free nuclear transmutation processes

Neutrons + atomic nuclei ⟶ heavier elements + decay products

Neutron capture $\quad n + (Z, A) \rightarrow (Z, A+1)$

Beta decay $\quad (Z, A+1) \rightarrow (Z+1, A+1) + e^-_\beta + \bar{\nu}_e$

Neutron capture-driven transmutation of isotopes and elements

LENRs do not involve few-body fission or fusion processes

Safe ultralow energy neutrons created via many-body collective process

Neutrons are captured by target fuels which transmutes them and produces heat

Widom-Larsen theory explains hard radiation-free LENR transmutation of target fuels

Transmutation

Neutrons + target fuel atoms → heavier elements + decay products + heat

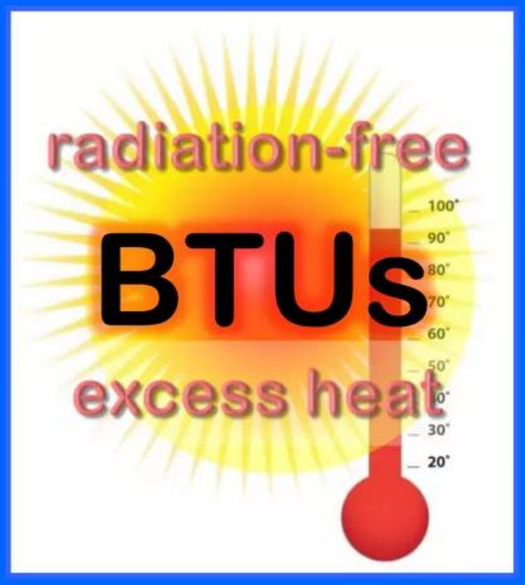
Catalytic neutron 'match'

Neutrons are readily captured by LENR target fuels such as Nickel (Ni), Titanium (Ti), Lithium (Li), or aromatic Carbon (C) atoms

Direct conversion of neutron capture and decay-related gammas to IR plus local β or α particle scattering create heat

neutron + capture

produces



LENR transmutation of fuel targets proceeds along rows of the Periodic Table

Widom-Larsen: input energy is required to produce neutrons

NEDO experiments: input energy mainly in form of blackbody IR photons

- **Input energy is required to trigger LENRs:** injection of input energy initiates far-from-equilibrium conditions that enable formation of nuclear-strength local E-fields which create populations of heavy-mass $e^{-}*$ electrons in nascent LENR active sites. Heavy-enough $e^{-}*$ are able to react directly with Q-M entangled p^{+} or d^{+} particles located in many-body active sites to produce catalytic ULE neutrons
- **NEDO project LENR reactor vessels are resonant electromagnetic (E-M) cavities:** energy input occurs by externally heating metal walls of reaction chambers (RC); this causes emission of broad-spectrum blackbody E-M radiation from inner walls of RC that irradiates LENR materials inside reactors. Surface plasmon electrons associated with surface nanostructures on LENR materials will absorb incident E-M photon energy (esp. from resonant infrared frequencies) and transport it to LENR active sites where ultralow energy neutrons are produced and captured
- **Relatively transparent to MeV gamma radiation, metal reactor walls are opaque to infrared (IR) radiation. When gamma conversion to IR occurs in LENR active sites, IR from down-converted gammas will be retained inside reactor cavity and be available to heat it up further. If energetic gain ratio in an LENR reactor is high enough, once it reaches required operating temperature range, external heaters could be turned-off.** In theory, such a reactor could continue to produce excess heat until key reactants are exhausted; in 1990s, poorly reproducible Italian Ni/H_2 gas experiments ran for up to 85 days and produced up to 900 MJ of excess heat

Public Lattice PowerPoint dated May 29, 2017 on SlideShare

U.S. Defense Threat Reduction Agency (DTRA) favorably evaluated Widom-Larsen theory of LENRs in official report originally published back in March 2010

Unclassified document recently became publicly available on the U.S. Dept. of Homeland Security's digital library website

Quoting from conclusions: "Could the W-L theory be the breakthrough needed to position LENR as a major source of carbon-free, environmentally clean … low-cost nuclear energy??"

Screenshots of key slides from now-public DTRA document reproduced herein

Lewis Larsen
President and CEO
May 29, 2017

Contact: 1-312-861-0115 Chicago, Illinois USA
lewisglarsen@gmail.com

https://www.slideshare.net/lewisglarsen/lattice-energy-llc-unclassified-2010-us-defense-threat-reduction-agency-powerpoint-favorably-evaluates-widomlarsen-theory-of-lenrs-may-29-2017

Key publications about Widom-Larsen theory of LENRs

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen (author's copy)
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)
http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen (author's copy)
Pramana - Journal of Physics 75 pp. 617 - 637 (March 2010)
http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen
Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)
http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"Hacking the Atom" (Volume 1 - 484 pages) popular science book
Steven B. Krivit, Pacific Oaks Press, San Rafael, CA, September 11, 2016
Paperback US$16.00; hardcover US$48.00; Kindle US$3.99
https://www.amazon.com/dp/0996886451

Working with Lattice Energy LLC, Chicago, Illinois USA

Partnering on LENR commercialization and consulting on other subjects

1-312-861-0115 lewisglarsen@gmail.com

L. Larsen c.v.: http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

- We believe Lattice is the world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our published peer-reviewed theoretical papers rigorously explain the breakthrough device physics of LENR processes, including the absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production
- Lattice welcomes inquiries from large, established organizations that have an interest in discussing the possibility of becoming Lattice's strategic capital and/or technology development partner
- Lewis Larsen also independently engages in consulting on variety of subject areas that include: Lithium-ion battery safety issues; long-term electricity grid reliability and resilience; and evaluating potential future impact of LENRs from a long-term investment risk management perspective for large CAPEX projects in the oil & gas, petrochemicals, transportation, utility, and aerospace industries