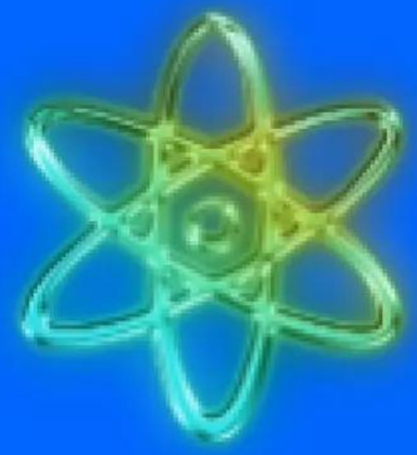
Ultralow energy neutron reactions (LENRs)

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

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Three types of nuclear power: fission, fusion, and LENRs

Fission now used for propulsion in naval aircraft carriers & submarines

LENRs great improvement vs. fission & fusion: no deadly radiation or radwastes

TRL = technology readiness level MeV = Megaelectron Volt = 1 million (10^6) eV

Heat producing nuclear process	Energetic MeV gamma γ radiation?	Energetic MeV neutron radiation?	Long-lived radioactive waste products?	Basic description of nuclear process which creates heat that can be harvested and converted	Scale of energy release (MeV) versus chemical (eVs)
Fission TRL 9^+ Uranium^{235}	Yes	Yes	Yes	Unstable heavy nuclei capture neutrons and shatter into fragments	~ 200 MeV complex mix of end-products
Fusion TRL $4^{+\ 2018}$ ITER D+T reactor in France^{2025}	Yes All fusion	Yes For D+T	No Induced	Gigantic temperatures enable light ionized nuclei to smash together and then fuse into heavier chemical elements	Depending on specific fusion reaction, value ranges from ~ 3 to ~ 24 MeV
LENRs TRL 4 In 2017 Japanese project had best-ever LENR heat production	No Heavy electrons convert γ into IR	No ~ All ULE neutrons captured locally	No Neutron-rich LENR products decay fast	Input energy creates ultra low energy neutrons (via $e + p$ reaction) that capture on target fuels. Gammas from neutron captures are converted into infrared; unstable products fast-decay into stable elements	Depending on fuels and subsequent reactions as well as decays, values range from ~ 0.1 MeV up to ~ 22 MeV

IR = infrared (heat)

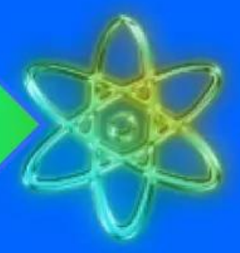
Revolutionary ultralow energy neutron reactions (LENRs)

Radiation-free LENRs transmute stable elements to other stable elements

Nuclear Fission and fusion

Disruptive new energy source

Evolution of greener nuclear technology



Nuclear Transmutation

No deadly MeV-energy gamma radiation

No dangerous energetic neutron radiation

Insignificant production of radioactive waste

Vastly higher energies vs. chemical processes

Revolutionary, no CO_2 , and environmentally green

Totally explained by physics of Widom-Larsen theory

Periodic Table of chemical elements found in the Universe

LENR transmutation of target fuels proceeds from left-to-right along rows

Any element/isotope in Periodic Table able to capture neutrons can serve as an LENR target fuel; some perform better and release more excess heat versus others, e.g. Li, Ni, Ti, C, W, etc.

Li = Lithium
Ni = Nickel
C = Carbon

Widom-Larsen theory provides device engineering guidance

LENRs not useful for making nuclear weapons or fissile U & Pu isotopes

- **Non-proprietary basic science of Widom-Larsen theory is published in peer-reviewed academic physics journals:** only LENR theory able to explain all good experimental data and guide commercial thermal device engineering efforts
- **LENRs use ultralow energy neutrons (ULEN - produced by direct reaction of protons with electrons) that are captured by stable target fuels:** ULE neutron capture process releases nuclear binding energy from fuels in form of clean heat and transmutes target fuels into other stable, non-radioactive elements
- **Any stable element that captures neutrons can be used as target fuel:** some perform much better than others, e.g., Nickel, Lithium, and aromatic Carbon
- **Per Widom-Larsen theory, LENRs *only* occur in discrete, nm- to μ-scale active sites found on surfaces or at interfaces:** LENR device thermal output scales upward as function of total working surface area & active site area-densities
- **Direct relationship between rates of ULE neutron production and amounts of input energy injected:** control of total input energy regulates rates of neutron production. **No neutron-multiplier effect as in fission process:** no risk of LENR runaway chain reactions; also means LENRs are not useful for making bombs
- **LENRs are non-proliferating:** ULEN transmutation not useful for making fissile or fertile isotopes because it creates mixtures of useless transuranic elements

LENRs do not produce hard energetic radiation or radwastes

Lack of any hard radiation obviates need for shielding and containment

Enables development of safe, battery-like, portable nuclear power sources

Today:
large Uranium fission power plants

Utility reactors require ~3 feet of concrete and ~1 foot of steel to shield humans from high-energy neutron & gamma radiation and highly radioactive wastes produced inside steel reactor vessel

Revolution in green nuclear technology

Future:
small systems

LENRs scale downward into small safe systems

Radiation-free ultralow energy neutron reactions (LENRs)

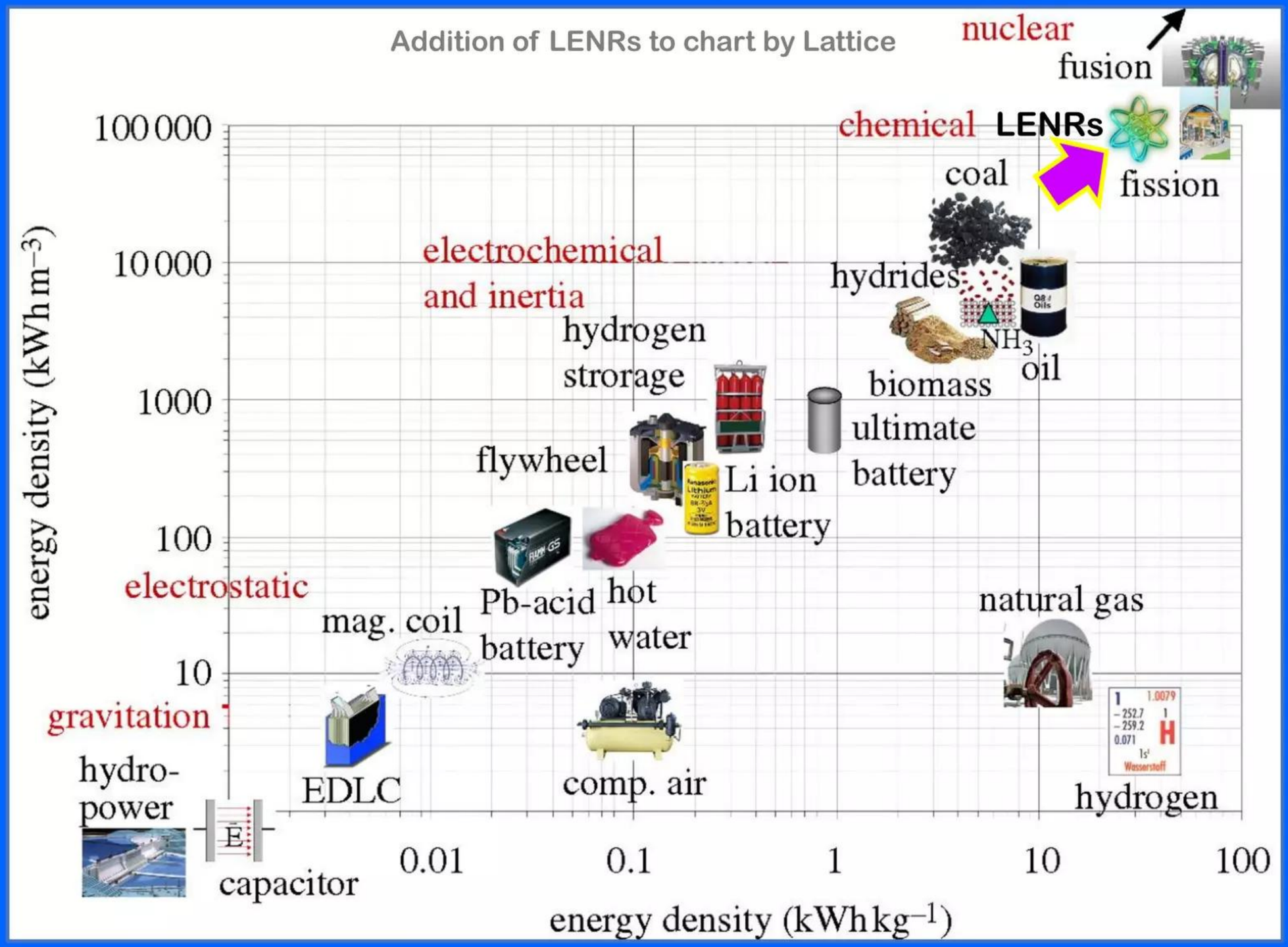
Absence of radiation and radwaste = game-changing energy technology

Greenness should make LENR power systems vastly less expensive than fission

- Unlike nuclear fission and fusion: heat-producing LENRs do not emit any deadly energetic 'hard' gamma and neutron radiation or make hazardous long-lived radioactive wastes
- Consequence: future LENR power generation systems would not require heavy, expensive radiation shielding and containment subsystems for safe long-duration operation
- Enables: LENR-based power systems to be vastly smaller and less expensive than fission or fusion reactors as well as light-enough to be safely utilized in unshielded propulsion systems for vehicles, aircraft, watercraft, and spacecraft
- Enables: eventual development of small, portable LENR power systems that would be safe, disposable after use in direct competition with chemical batteries and fuel cells

Energy density of technologies from hydropower to fusion

Fig. 7 in "Hydrogen: the future energy carrier" A. Zuttel *et al.*
***Phil. Trans. R. Soc. A* 368 pp. 3329 - 3342 (2010)**



Nuclear energy density: enormous advantage vs. chemical

LENR energy releases fall between fission and chemical power sources

Certain LENRs can release even more energy than D + T nuclear fusion reaction

Fission and fusion known for ~ 80 years; H_2 fuel cells and gasoline > 100 years

First reports of what are now known to be LENRs were published in early 1900s, but were neither understood nor recognized as being a nuclear process because easily detected hard radiation was absent

Reaction Type	Typical "Average" Energy Release		Relative Index of Energy Release	
U-235 Conventional Fission (1938)	200 MeV		1000	Fission and fusion
H+H Fusion in Stars (1939)	27 MeV	Nuclear: Strong Interaction	123	
D+T Fusion Reactors (1950s)	17. 6 MeV		80	
	~ 22 MeV (high side)	Nuclear: Weak Interaction	91	LENRs
	~ 0.1 MeV (low side)		0.45	
Hydrogen Fuel Cells (1838)	0.0002 MeV	Chemical	0.0001	Chemical
Combustion of Gasoline (1876)	0.0001 MeV		0.00005	

Evolution of nuclear

LENRs (Hydrogen, Deuterium) were rediscovered by P&F in 1989

Nuclear energy density surpasses all chemical technologies

LENR-based power generation: huge competitive advantage vs. chemical

LENRs for military power & propulsion could boost combat system performance

LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators		
Source of Energy	**Approximate Energy Density (Watt*hours/kg)**	
Alkaline Battery	**164**	Electrochemical
Lithium Battery	**329 to 600**	Electrochemical
Zinc-Air Battery	**460**	Electrochemical
Direct Methanol Fuel Cell (35% efficient)	**1,680**	Electrochemical
Gas Burning Microgenerator (20% efficient)	**2,300**	Combustion
100% Efficient Combustion of Pure Methanol	**5,930**	Combustion
100% Efficient Combustion of Pure Gasoline	**11,500**	Combustion
LENRs (based on an assumption of an average of 0.5 MeV per nuclear reaction in an LENR system)	**57,500,000** (maximum theoretical energy density – only a fraction would be achievable in practice)	LENRs

~2,000 Wh/kg may be practical limit with Lithium-air (Oxygen) Theoretical maximum: Li/air = ~11,680 Wh/kg

Nanoparticulate LENR fuels could be used in many systems

Possible LENR target fuels include: Nickel, Lithium & aromatic Carbon

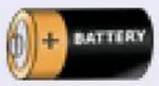
Commercial LENR fuel energy densities could be > 5,000x larger vs. gasoline

- **High energy density:** motor vehicles, aircraft, or very small ships powered by LENRs could travel around entire world on quantity of nanoparticulate fuel that would fit into 2 large FedEx boxes. LENR fuels would be inert and benign and could utilize overnight package delivery systems or UAVs for resupply
- **Size of fuel logistics pipelines would collapse:** typical gasoline or diesel tanker trucks as shown below carry ~ 5,000 to 12,000 US Gallons of liquid fuel. LENR fuels producing same # of BTUs could fit into 1 or 2 FedEx boxes

LENRs enable safe nuclear power for many types of systems

Fission superb for power & propulsion when size or weight aren't critical

Energy density of LENRs between nuclear fission and chemical power sources

Icon	Fuel type or storage material	Type of Energy Released	Specific Energy (MJ/kg)	Key Applications For Technology
	Uranium- 235 Commercially deployed and used by military TRL (TRA) stage = 9+	Nuclear Fission First reactor – 1942 Military and commercial	Estimated 80,620,000 (breeder reactor)	Electric power plants, aircraft carriers, subs, and nuclear weapons
	Thorium-232 TRL = 8	Nuclear Fission Under development	Estimated 79,420,000 (breeder reactor)	Electric power plants (shorter-lived radwastes vs. ^{235}U)
	LENRs TRL = 4 Stable Nickel target fuel (stable Lithium would be ~ 2x higher in MJ/kg)	Nuclear, but neither fission nor fusion. Most recent rediscovery of LENR effects in 1989	Estimated ~ 3,817,235 Optimized commercial Ni-fueled power systems	Electric power plants; stationary, mobile, as well as portable power & propulsion applications
	Hydrogen gas (compressed to 70 MPa)	Chemical - combustion	142	Rocket & auto engines, grid storage & conversion
	Diesel, fuel oil	Chemical - combustion	48	Automotive engines, power and propulsion
	LPG (incl. Propane, Butane)	Chemical - combustion	46.4	Cooking, home heating, auto engines, lighters
	Jet fuel	Chemical - combustion	46	Aircraft
	Gasoline	Chemical - combustion	44.4	Automotive engines, power and propulsion
	Ethanol (E100)	Chemical - combustion	26.4	Flex-fuel, racing, lighting
	Methanol fuel (M100)	Chemical - combustion	19.7	Racing, model engines
	OTTO fuel II (monoprop.)	Chemical - combustion	2.3	Torpedo propulsion
	Lithium-ion battery	Electrochemical	2.2	Portable electronics

Batteries & OTTO-like fuels power UW drones and torpedoes

Monopropellant fuels (OTTO II) generally > energy density vs. batteries

New French Navy heavyweight torpedo: FN21
(Silver oxide-aluminum sea-water primary battery)

DCNS
40-42, rue du Docteur Finlay
F-75732 Paris Cedex 15
www.dcnsgroup.com

THEORETICAL CHEMICAL ENERGY DENSITY COMPARISON	
Silver oxide-aluminium (AgO-Al)	1,040 Wh/kg
Silver oxide-zinc (AgO-Zn)	490 Wh/kg
Lithium-Ion (Li-Ion)	600 Wh/kg
Lithium-polymer	600 Wh/kg
Lithium-iron phosphate ($LiFePO_4$)	520 Wh/kg
OTTO fuel II	645 Wh/kg*

https://www.naval-group.com/wp-content/uploads/2017/01/f21-the-french-navys-new-heavyweight-torpedo.pdf

U.S. Navy heavyweight torpedo:
MK- 48 ADCAP (OTTO fuel II)

Challenge: Putin claimed nuclear-powered underwater drone

Powered by compact fission reactor reputed to be operational Dec. 2017

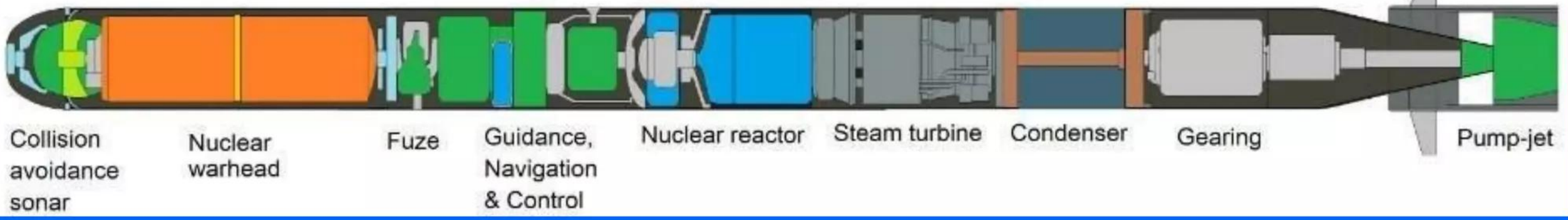
Speed claimed for drone is faster than surface ships or torpedoes in use today

Autonomous submarine drone's stated length 24 m (79 ft.); diameter 1.6 m (5.5 ft.)

KANYON larger than many ICBMs  **Most underwater drones are smaller**

U.S. code name = KANYON (Russia "Status-6" - now called "Poseidon")

U.S. Navy built & operated ~400 ton 3.5 knot manned sub with even smaller fission reactor
General Dynamics NR-1 (1967-2008): GE PW U^{235} ~100 kW thermal (< 45 kW electric)

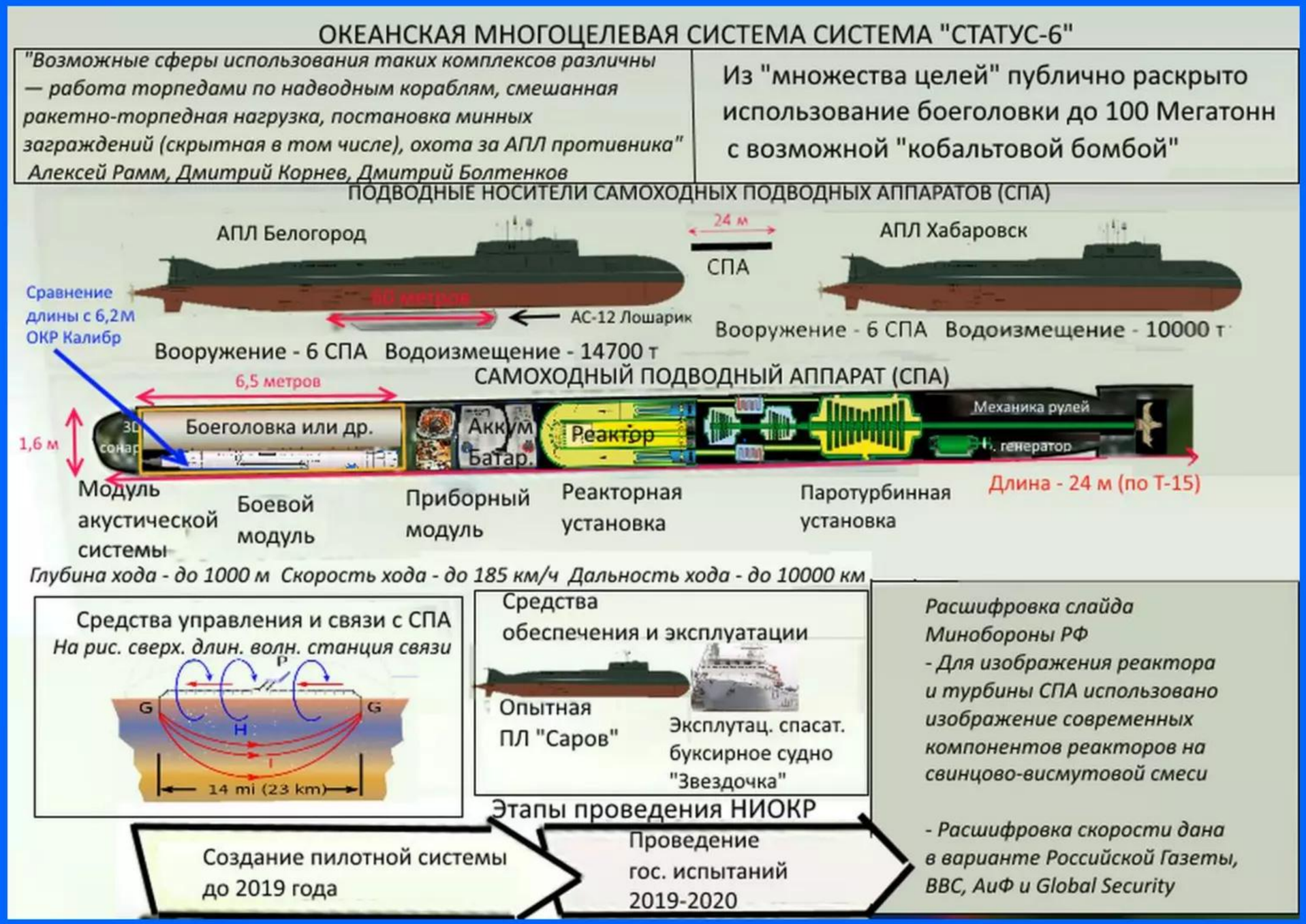


Autonomous underwater drone resembles giant naval torpedo

Built by Rubin Design Bureau, largest of Russia's three submarine manufacturers. According to reports on Russian television: drone's range is 6,200 miles, top sprint speed is greater than 56 knots, and able to operate at depths up to 3,280 feet (≅ NR-1)

U.S. military confirmed new Russian nuclear UW drone exists

Should U.S. develop similar fission drone or leapfrog with newer LENRs?



https://www.defensenews.com/space/2018/01/12/russias-nuclear-underwater-drone-is-real-and-in-the-nuclear-posture-review/

“Army of none - autonomous weapons and the future of war”

Paul Scharre - former Army Ranger and DoD analyst - Norton (April 2018)

Yesterday’s science fiction can become tomorrow’s reality - where life imitates art

Short video: “Slaughterbots”
7 min. 47 sec. (2017)

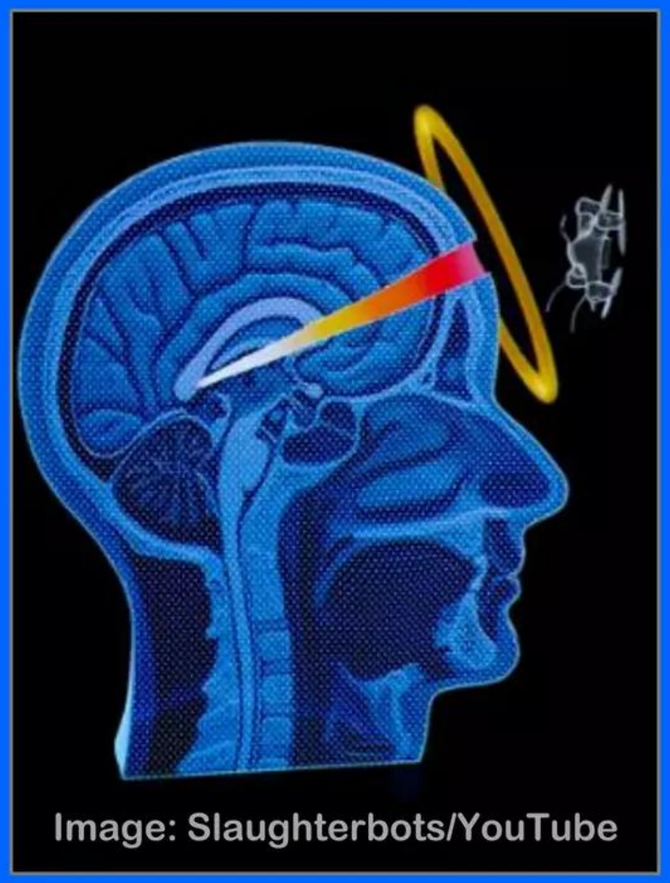
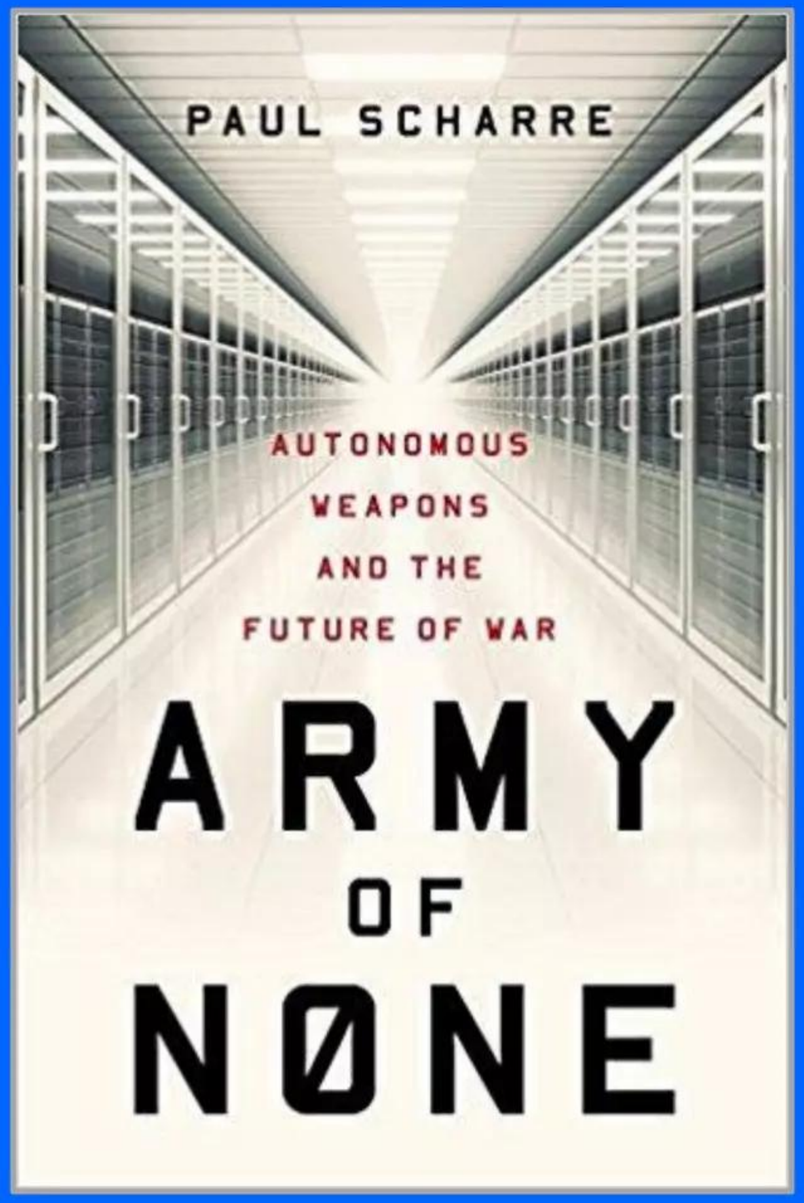


Image: Slaughterbots/YouTube

http://autonomousweapons.org/slaughterbots/



Autonomous “Terminator”
T-800 was nuclear-powered

Image: Orion Pictures

“The Terminator” was cult-classic 1984 American science fiction film starring Arnold Schwarzenegger

https://spectrum.ieee.org/automaton/robotics/military-robots/why-you-shouldnt-fear-slaughterbots

https://www.amazon.com/Army-None-Autonomous-Weapons-Future/dp/0393608980

LENR systems could be > 10x - 100x chemical energy density

Power & propulsion with LENRs could provide game-changing advantage

Big energy densities of LENR fuels could radically alter design of aircraft & robots

Combat system performance parameters that could be greatly improved by using LENRs for power and propulsion:

- Speed
- Altitude (aircraft)
- Range of mission
- Endurance of mission
- Payload or cargo capacity/mass
- Better creature comforts (manned systems)
- Logistics requirements for fuel resupply tails
- Onboard power for propulsion, weapons, e.g. fiber lasers, communications, sensors, as well as for other electronic and computational subsystems, e.g. jammers, AI computers

Image credit: DARPA

LENR fuel energy density: massive impact on aircraft design

Two FedEx boxes could likely hold enough LENR fuel for SR-71 mission

Huge advantage in using LENR propulsion technology: energy densities of onboard fuels at least 5,000x > gasoline; fuel fraction could be cut by ~ 90%

LOCKHEED MARTIN

SR-71 Blackbird carried ~12,000 gallons of JP-7 aviation fuel with full tanks; permitted unrefueled range of 3,250 miles flying @ Mach 3 (2,284 mph)

Fuel comprised 65% of takeoff weight

Fuel fraction = onboard fuel as % of an aircraft's total weight at takeoff:

Ford F-150 truck only 3%

Boeing 737-600 27%
F-22 Raptor 29%
Predator MQ-1 drone 30%
Eurofighter 31%
F-35 Lightning JSF 33%
Airbus A380 44%
Mig-31 Foxhound 45%
Concorde SST 50%
B2 Spirit bomber 50%
SR-71 Blackbird 65%
Rutan Voyager 72%
V.A. GlobalFlyer 83%

Missiles (typical) > 85%
Saturn-5 (moon) 96%

LENR power & propulsion boost range/endurance 10x - 100x

Examples assume no speed increases: show impact on range/endurance

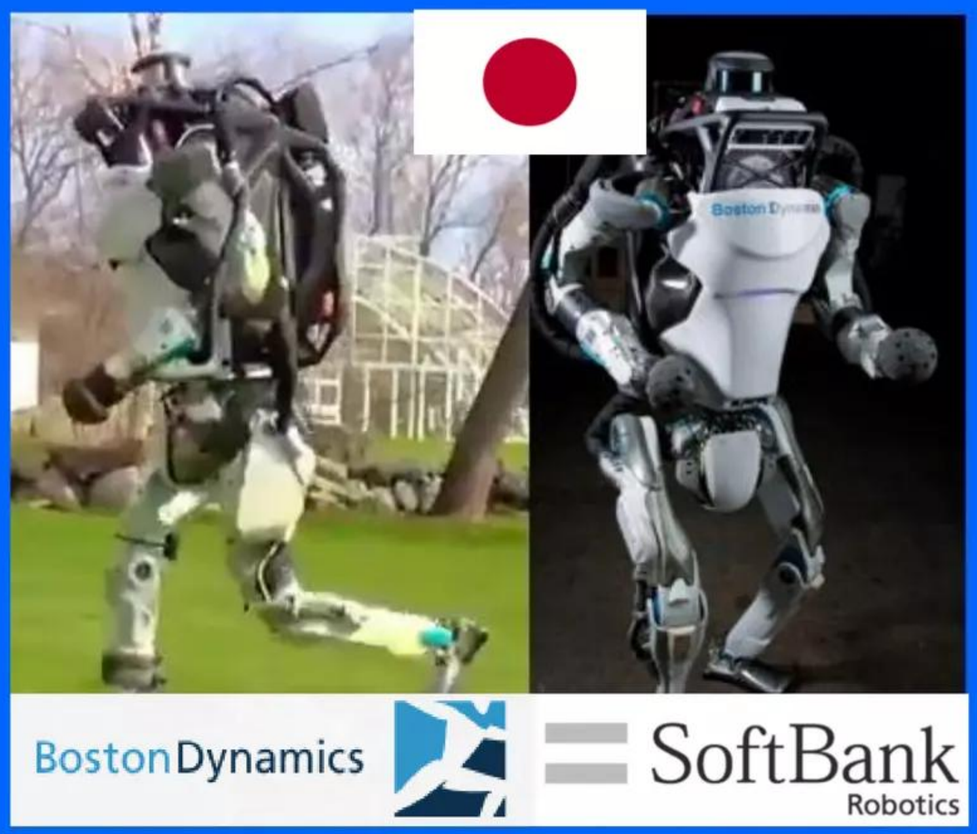
Systems	Present capabilities with today's battery and combustion-based power & propulsion technologies	Range/endurance enhancement with future LENR power sources	
		10x chemical	100x chemical
Insectoid recon bots and "slaughterbots"	Science fiction today … but tomorrow ???	24 - 48 hours ???	days to months ???
Yuneec Typhoon H920 Plus (China)	State-of-the-art commercial hexacopter 12.4 miles: 24 minutes @ 31 mph cruise	124 m (4 hrs. @ 31 mph cruise)	1,240 m (40 hrs. @ 31 mph cruise)
Predator MQ-1 drone General Atomics (US)	24 hours @ max 135 mph (est. 84 cruise) Discrepancy - mfgr. says range 770 miles	7,700 m (~ 3.8 days @ 84 mph cruise)	77,000 m (~ 38 days @ 84 mph cruise)
Super Heron drone (Israeli Aircraft Ind.)	45 hours @ max 173 mph (est. 121 cruise) Discrepancy - mfgr. says range 621 miles	6,210 m (~ 2.1 days @ 121 mph cruise)	62,100 m (~ 21 days @ 121 mph cruise)
Tesla Model S (2018)	Typical ~ 335 miles: 4 - 5 hours @ 70 mph	3,350 m (50 hrs.)	33,500 m (500 hrs.)
Bluefin-21 drone (US)	75 nautical miles: 25 hours @ 3 knots (GD)	750 nm (10.4 days)	7,500 nm (104 days)
Mark- 48 torpedo (US)	31 nautical miles: 33 min. @ 56 knots	310 nm (5.5 hrs.)	3,100 nm (55 hrs.)
"Khishchnik" torpedo (supercav. - Russia)	70 nautical miles: < 21 min. @ > 200 knots "Elektropribor" (G. Savchenko est., 2017)	700 nm (3.5 hrs. @ 200 knots cruise)	7,000 nm (35 hrs. @ 200 knots cruise)
Exoskeletons and combat "power suits"	Present batteries severely limit endurance without access to external power sources	Duration of autonomous activity could be increased up to a week or even months	
Autonomous biomech military robots	Present batteries severely limit endurance without access to external power sources	Duration of autonomous activity could be increased up to a week or even months	

Mobility & performance of humanoid robots greatly improved

Military exoskeletons also improved but need 3 - 15 kW of onboard power

Energy density of batteries insufficient for militarily significant mission endurance

3.7 kWh Li-ion battery lasts 1 hour



Video of BD "Atlas" robot jogging:
https://www.youtube.com/watch?v=g3qi-L5GPSM

Near-future: powered exoskeletons and combat suits

March 2018:
https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=9ba5618073c7bfa2d4abd42e1f5c4ee4

Newsweek "Russia has developed Titanium exoskeleton for future wars --- but it has one problem" by Damien Sharkov *Newsweek* Dec. 15, 2017

Semyonov said: "However, the matter of creating such a battery is not solved anywhere in the world. This is a shared problem." [needs capable power source!]

http://www.newsweek.com/russia-has-made-titanium-exoskeleton-future-wars-it-has-one-problem-749569

2012: Boeing filed a patent claiming LENRs as energy source

EP 2,730,501 A2: acoustic stealth propulsion from subsonic to supersonic

Invention claims scalability from small ~20 kg UAVs up to large passenger aircraft

Europaisches Patentamt
European Patent Office
Office européen des brevets

Well-written application and clever aeronautical propulsion invention:

- "Rotational annular airscrew with integrated acoustic arrester"
- EP 2,730,501 A2 (English)
- Inventors: Matthew D. Moore and Kelly L. Boren (both from Everett, WA)
- Original USPTO filing date as US 201213674377 was November 12, 2012
- EPO application publication date: May 14, 2014

Contra-rotating fan blades

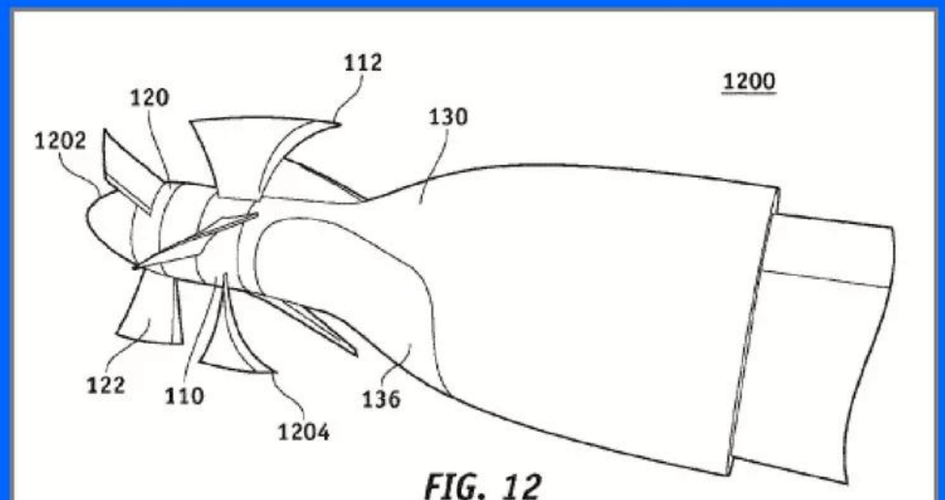


FIG. 12

Fan blades enshrouded within nacelle

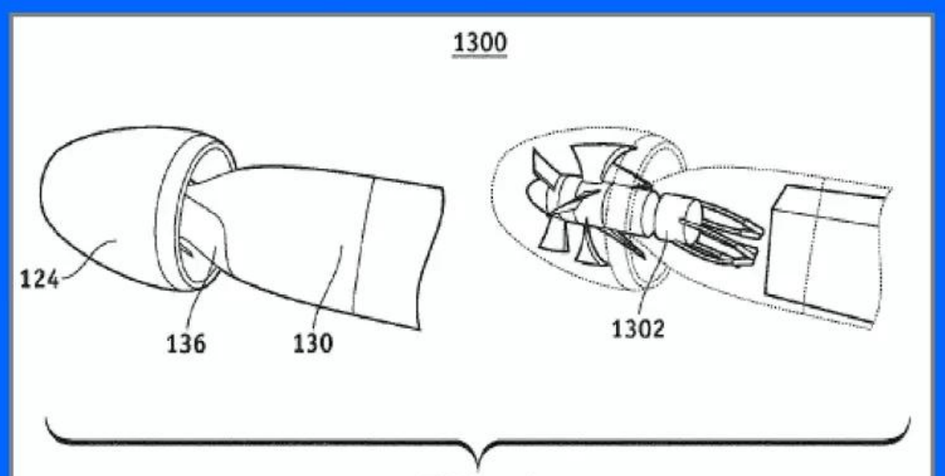


FIG. 13

https://data.epo.org/gpi/EP2730501A2-Rotational-annular-airscrew-with-integrated-acoustic-arrester

2012: Boeing filed a patent claiming LENRs as energy source

EP 2,730,501 A2: acoustic stealth propulsion from subsonic to supersonic

Separate electric motors used to power each set of fan blades in one embodiment

In this EP application please see page #7, column 11, paragraph 0032 as follows (quoting):

"[0032] The contra-rotating forward coaxial electric motor 126 and the contra-rotating aft coaxial electric motor 128 are coupled to at least one energy source. The contra-rotating forward coaxial electric motor 126 and the contra-rotating aft coaxial electric motor 128 may be directly coupled to the at least one energy source, or through various control and/or power distribution circuits. The energy source may comprise, for example, a system to convert chemical, solar or nuclear energy into electricity within or coupled to a volume bearing structure. The energy source may comprise, for example but without limitation, a battery, a fuel cell, a solar cell, an energy harvesting device, low energy nuclear reactor (LENR), a hybrid propulsion system, or other energy source."

UAV embodiment

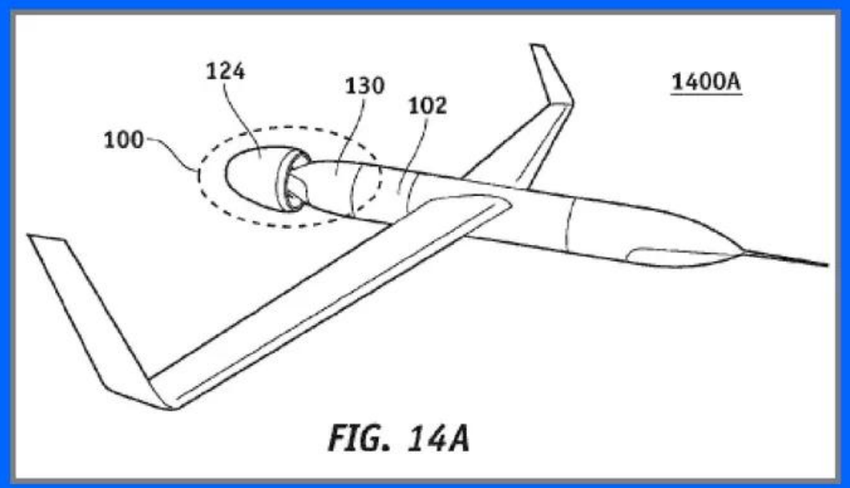


FIG. 14A

Passenger aircraft embodiment

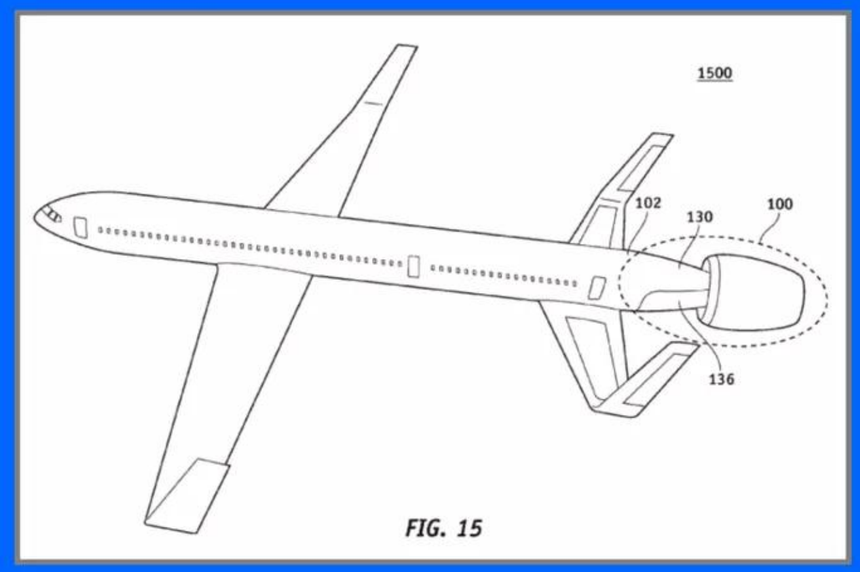
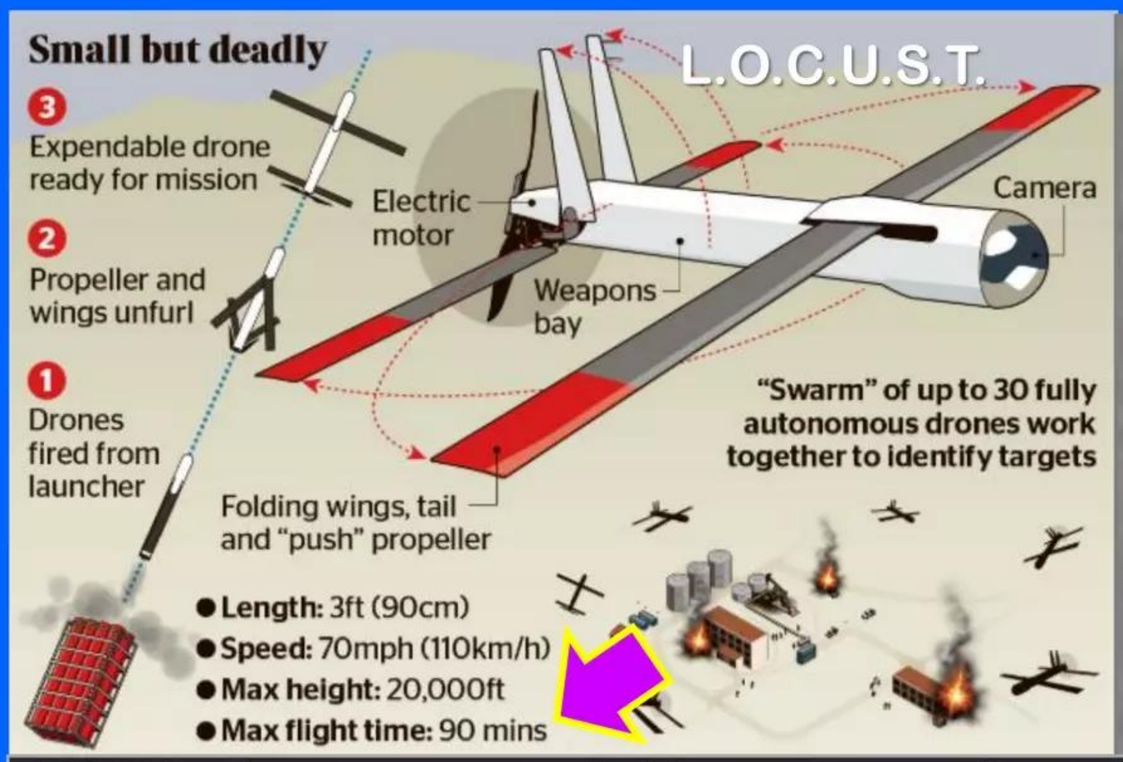


FIG. 15

LENRs amplify combat power for traditional weapon systems

Today's drones have <<< less endurance/speed than planes, ships, subs

New force-multipliers: coordinated swarms of surveillance and armed LENR drones



"UAVs that are expendable and reconfigurable will free manned aircraft and traditional weapon systems to do more, and essentially multiply combat power at decreased risk to the warfighter"

- Lee Mastroianni, Office of Naval Research Program Manager

Houston Mechatronics "Aquanaut" morphing UUV

Festo's seagull look-alike "SmartBird"

Boston Engineering 4-foot "Robo-tuna"

LENR technology could end eras of vulnerable fuel convoys

Resupply of FOBs would involve small numbers of vehicles or UAVs

"One in eight Army casualties has been the result of protecting fuel convoys"

"Local residents watch burning NATO supply oil tankers following an attack by gunmen on the main highway at Kolpur village, 25 kilometres (15 miles) south of Quetta, the capital of the restive Baluchistan province. Gunmen on motorbikes in southwestern Pakistan set ablaze at least 19 oil tankers carrying fuel for US-led NATO forces in neighbouring Afghanistan."

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

Best-ever experimental results recently reported by NEDO project (Japan)

- **Experimental results released from Jan. to April 2018 by Technova Inc.:** revealed LENR device fabrication & testing R&D project funded by Japanese government's New Energy and Industrial Technology Development Organization (NEDO) clearly achieved TRL-4 after technology had stagnated globally at ~ TRL-3 for > 10 years. **Best, most advanced experimental work now being conducted by NEDO in Japan**
- **NEDO's LENR R&D project is a well-organized government-business-academic consortium:** comprised of Mitsubishi Heavy Industries, Toyota, Nissan Motors as well as four respected Japanese universities: Tohoku, Nagoya, Kobe, and Kyushu
- While Japanese automakers now pursuing LENRs do not speak to the news media about programs, ultimate goal may well be to replace internal combustion engines
- **NEDO project advanced LENR technology from TRL-3 to TRL-4 in ~2.5 years at cost of < US$ 54 million:** greatly accelerated progress by leveraging nanotech & materials science. Wittingly or not, R&D strategy pursued by project scientists effectively followed experimental guidance provided by Widom-Larsen theory
- Best-ever, state-of-the-art LENR device heat production results: 1-25 Watts for 1-45 days (NEDO - 80% success rate: Ni/Pd/Zr-H_2/D_2). **Individuals or organizations who presently claim to have working LENR devices that can produce 1 kilowatt or up to as much as 1 megawatt thermal are dubious at best and not to be believed**

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/

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

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

Cost to develop 1st commercial/military product could be < US$ 1 billion

- **Compared to Japan:** much smaller corporate, academic, and/or government R&D programs to commercialize LENRs underway in U.S., India, China, Russia, and EU
- **Future development of LENR power & propulsion technology could potentially advance very rapidly beyond TRL-4 and catch many by surprise.** This is possible because Widom-Larsen theory and proprietary nanotech & materials science know-how can be leveraged to accelerate progress toward commercialization
- **Beyond TRL-4, Lattice believes major improvements in device reproducibility and scale-up of excess heat production will require:** mastery of design, fabrication, and emplacement of device nanostructures that function as precursors to μ-scale Widom-Larsen theory LENR active sites. Achieving goal should result in reliable LENR devices where quantity of heat production is predictable and controllable. Thermal output could then be scaled upward by increasing total working surface area in devices and/or boosting area-densities of LENR active sites on surfaces
- **Over 28 years prior to NEDO funding its LENR project, total cumulative worldwide R&D spending on LENRs was likely < US$ 250 million.** Thru 2018, total cumulative global R&D spending on LENRs since 1989 probably < US$ 300 million (10 M$/yr.). Today, number of scientists working full-time on LENR R&D is likely < 200 people worldwide. **Lattice believes that < US$ 1 billion and 5 - 7 years would be needed to move from TRL-4 to TRL-9 with first commercial/military product being 1 - 10 kW (electrical) stationary power generation system fueled with Lithium or Nickel & H_2**

U.S. Naval Institute acknowledged future potential of LENRs

3rd annual USNI-Leidos emerging & disruptive technology essay contest

April 10, 2018: 2nd prize awarded to NAVSEA employee for essay about LENRs

"Low Energy Nuclear Reactions: A potential new source of energy to facilitate emergent/disruptive technologies"

By Michael Ravnitzky - to be published in future issue of *Proceedings*

https://twitter.com/lewisglarsen/status/987351188801773570

U.S. Navy has had episodic if unknowing encounters with LENRs as far back as 1953, when physicist Edward Trounson, working at the Naval Ordnance Laboratory, successfully repeated experiments that had been first conducted by Ernest Sternglass while at Cornell University in 1951:

"Einstein's lost hypothesis: is a third-act twist to nuclear energy at hand?" Mark Anderson in *Nautilus* magazine, pp. 21 - 29 Winter 2013-14 issue Nov. 28, 2013

http://nautil.us/issue/7/waste/einsteins-lost-hypothesis

https://www.slideshare.net/lewisglarsen/lattice-energy-llclenrs-ca-1950ssternglass-exptseinstein-bethenov-25-2011

“So, so you think you can tell, Heaven from Hell?”

Pink Floyd “Wish You Were Here” 1975

Choices must be made: autonomous military drones powered by AI and LENRs could have unprecedented intelligence and endurance. They could quietly infiltrate Earth’s seabeds, forests, and cities to ‘sleep’ until they are summoned to awaken and complete their missions in a dystopian future akin to the apocalyptic vision in English poet John Donne’s quatrains:

“At the round earth’s imagin’d corners’
Blow ye trumpets angels and
Arise from death, ye numberless infinities of souls and
To your scattered bodies go …
But let them sleep Lord, and me mourn a space,
For if above all my sins abound,
‘Tis late to ask abundance of thy grace.”

Holy Sonnet 7 circa 1623

Paul Scharre ends his book “Army of None” (2018) with quote from a movie character:

“There is no Fate but what we make.”

Sarah Connor TERMINATOR 2 JUDGMENT DAY **Carolco Pictures (1991)**

Image credit: Tripod war machine just after emerging from ground in “War of the Worlds” Paramount Pictures (2005 film)

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

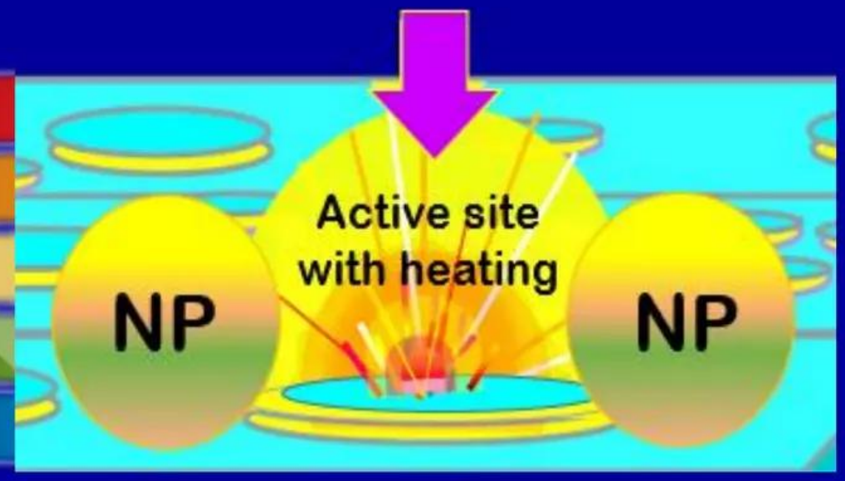
Modern nuclear physics

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

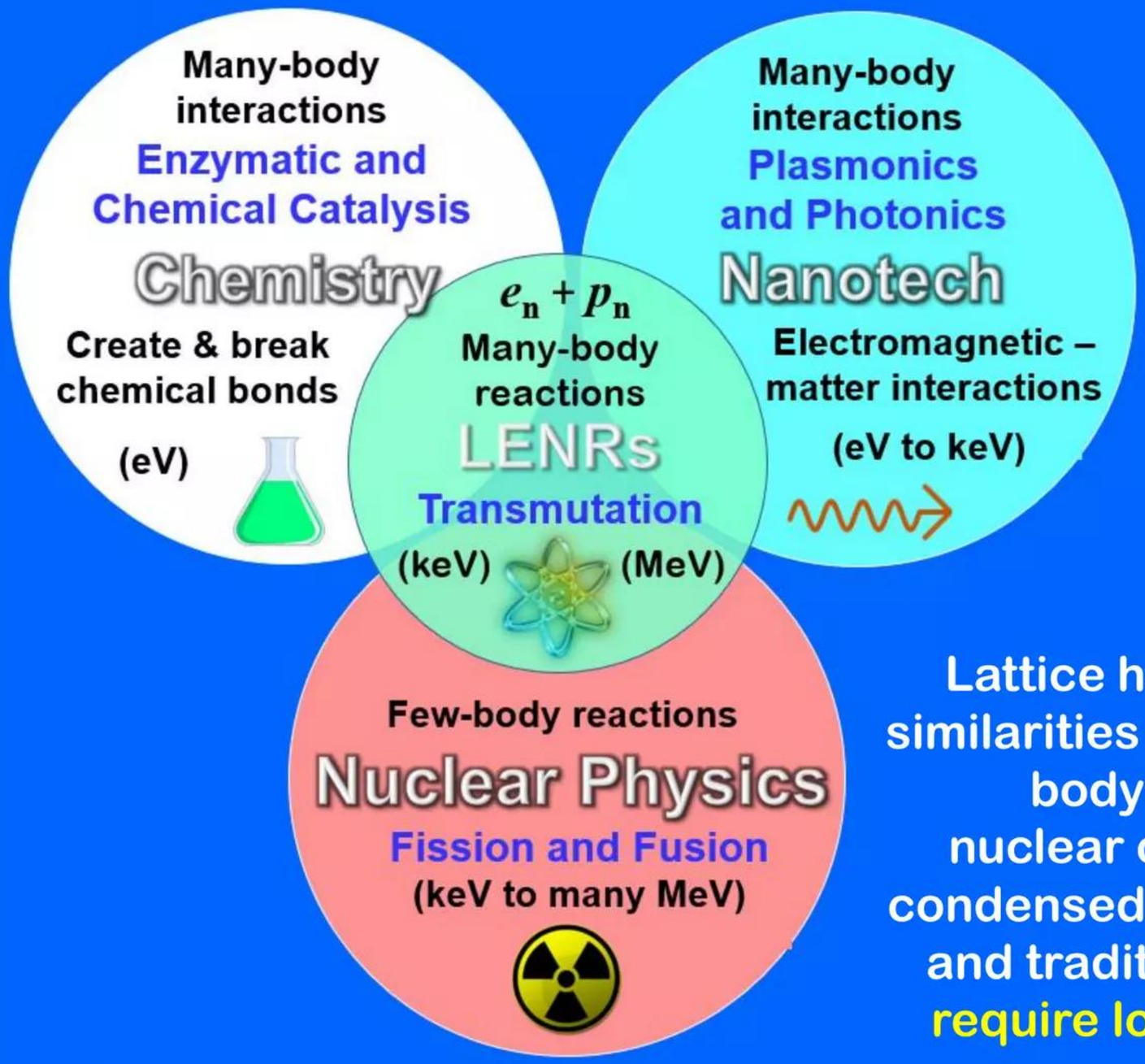
Micron (μm) to nanometer (nm) length-scales

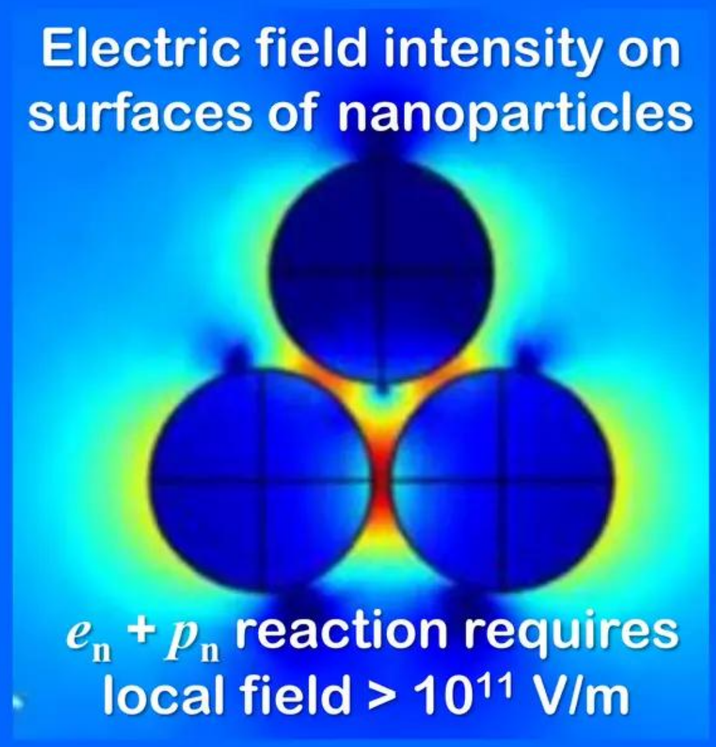
LENR active sites, as a key functional unit, are analogous to transistors in microchips

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

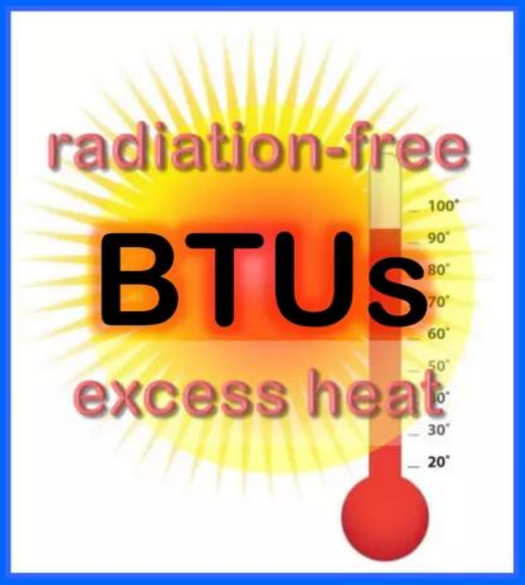
Catalytic neutron 'match'

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

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