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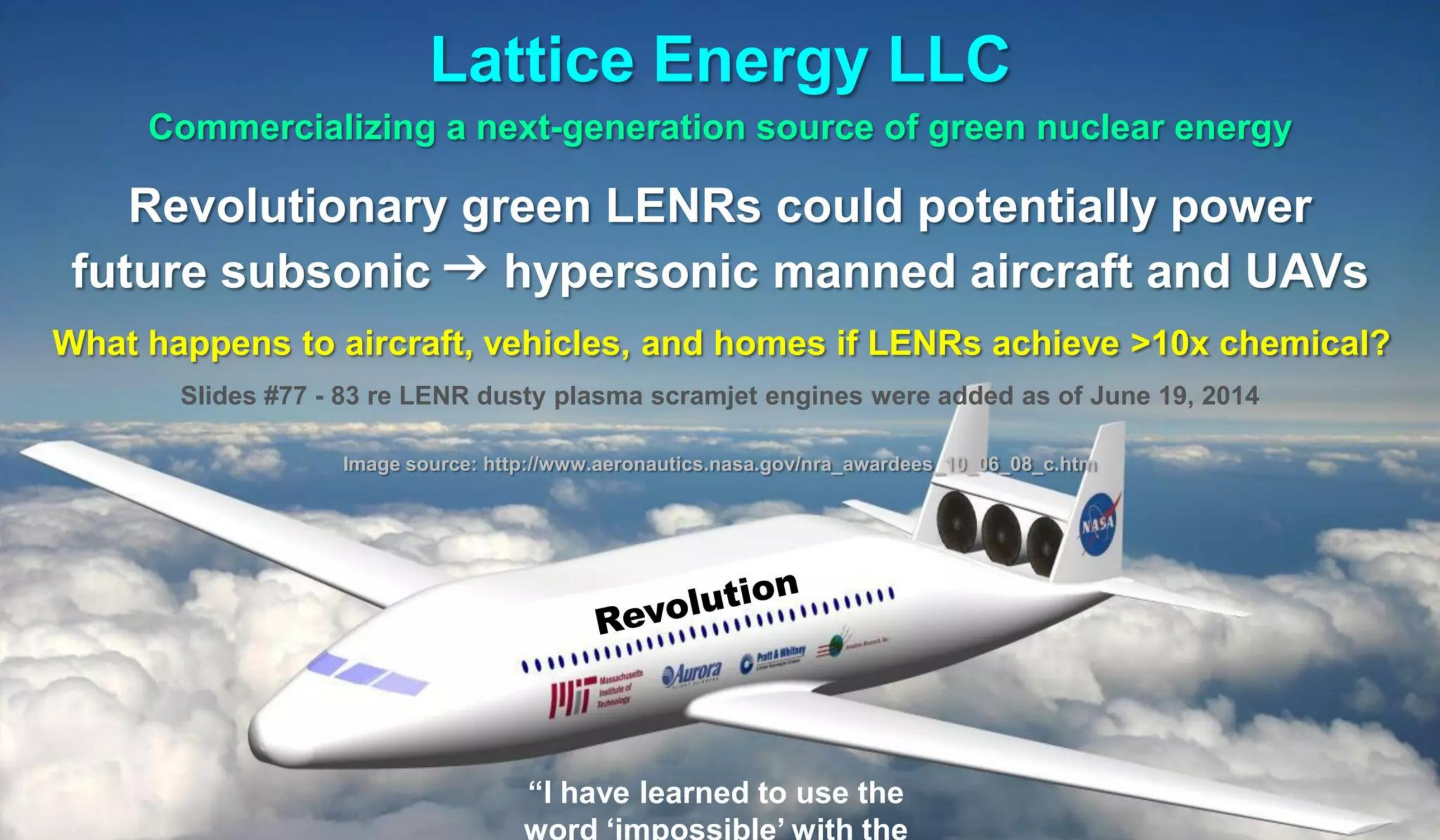
Commercializing a next-generation source of green nuclear energy

Revolutionary green LENRs could potentially power future subsonic → hypersonic manned aircraft and UAVs

What happens to aircraft, vehicles, and homes if LENRs achieve >10x chemical?

Slides #77 - 83 re LENR dusty plasma scramjet engines were added as of June 19, 2014

Image source: http://www.aeronautics.nasa.gov/nra_awardees_10_06_08_c.htm



"I have learned to use the word 'impossible' with the greatest of caution."

Werner von Braun

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http://www.slideshare.net/lewisglarsen/presentations

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NASA believes that LENRs are an "ideal energy solution"

Recent document reveals: studying possible use of LENRs to power future advanced green subsonic aircraft

http://nari.arc.nasa.gov/sites/default/files/attachments/17WELLS_ABSTRACT.pdf

Two screenshots of 1-page pdf Abstract (continues on next slide)

Low Energy Nuclear Reaction Aircraft

Investigator(s): Doug Wells, NASA Langley Research Center

Purpose

The purpose of this research is to investigate the potential vehicle performance impact of applying the emergent Low Energy Nuclear Reaction (LENR) technology to aircraft propulsion systems. LENR potentially has over 4,000 times the density of chemical energy with zero greenhouse gas or hydrocarbon emissions. This technology could enable the use of an abundance of inexpensive energy to remove active design constraints, leading to new aircraft designs with very low fuel consumption, low noise, and no emissions. The objectives of this project are to: (1) gather as many perspectives as possible on how and where to use LENR for aircraft including the benefits arising from its application, (2) explore the performance, safety, and operational impacts to individual aircraft and the fleet, (3) evaluate potential propulsion system concepts, and (4) foster multi- disciplinary interaction within NASA.

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NASA believes that LENRs are an "ideal energy solution"

Studying possible use of LENRs to power future green aircraft

Background

LENR is a type of nuclear energy and is expected to be clean, safe, portable, scalable, and abundant. The expected benefits make it an ideal energy solution. When it is applied to aircraft, LENR removes the environmental impacts of fuel burn and emission from combustion. Excess energy can be used to reduce noise so that all three of NASA's technology goals for future subsonic vehicles are either eliminated or addressed. Furthermore, aviation impacts almost every part of our daily lives, civilian and military. A revolutionary technology like LENR has the potential to completely change how businesses, military, and the country operate as a whole, giving a tremendous financial, tactical, and resource advantage to the country that utilizes it in the most effective way.

LENR creates some unique capabilities as well as challenges for integration into aircraft. The LENR concept that has reported most of the success generates heat in a catalyst process that combines nickel metal (Ni) with hydrogen gas (H). The initial testing and theory show that radiation and radioisotopes are extremely short lived and can be easily shielded. Although nuclear fission has been looked at for use in aircraft, LENR is different. LENR has a higher energy density and no radioactive by products.

Success of this research will provide a firm foundation for future research and investment for LENR technology integration into aircraft. Key research and development areas will be identified with any gaps in the current technology research. This research will guide NASA on the most effective way to invest in LENR to be the world leader in LENR aircraft research.

Source: http://nari.arc.nasa.gov/sites/default/files/attachments/17WELLS_ABSTRACT.pdf

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NASA believes LENRs can potentially power large aircraft

Feb. 25, 2014: LENR Aircraft - NARI Seedling Seminar (Doug Wells)

Conceptualization of very large *Sky Train* subsonic aircraft taking-off

Source: http://nari.arc.nasa.gov/sites/default/files/attachments/SeedlingSeminar2014.pdf

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NASA believes LENRs can potentially power large aircraft

Feb. 25, 2014: LENR Aircraft - NARI Seedling Seminar (Doug Wells)

LENR Aircraft NARI-Seedling-Seminar(3).pptx Full Screen

Propulsion Systems

NASA Aeronautics Research Institute

4. Brayton Cycle with LENR Nanoparticles

- New LENR combustor
  - Inject nickel nanoparticles like fuel
  - Forced convection with area change
  - Thrust is a function of m_{LENR} and T_{LENR}

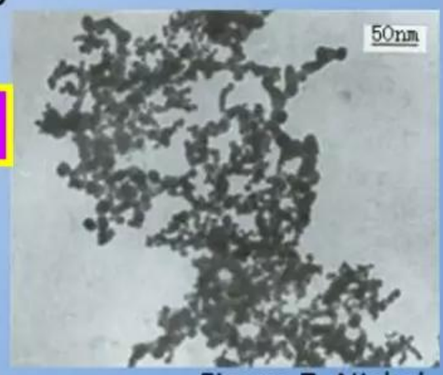

Figure 7: Nickel Nanoparticles[9]

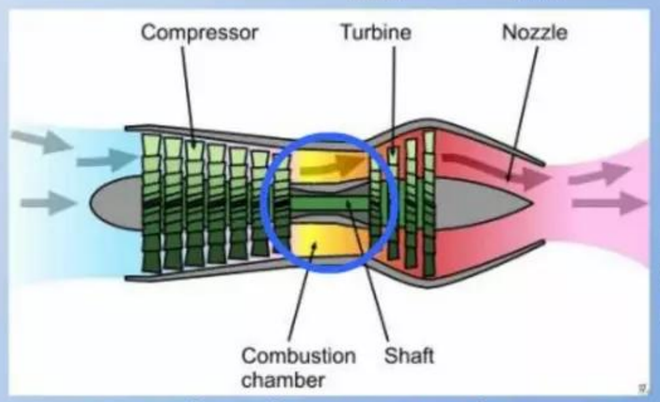

Figure 8: Schematic diagram of the operation of a axial flow turbojet engine[10]

- Compressor and turbine stay the same

[9]"Nanoparticles: Nickel [Ni]", Applied Nanotech Holdings, Inc., [internet catalog], 2013.
[10]Drawn using XaraXtreme by Emoscopes, 2005.

February 19–27, 2014 NASA Aeronautics Research Mission Directorate 2014 Seedling Technical Seminar 16

New Energy Times **(Steven Krivit) reported in 2012 about NASA's questionable shenanigans with Lattice:**
https://news.newenergytimes.net/2012/05/24/nasa-and-widom-larsen-theory-inside-story/

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McDonald *et al*. explore impact of LENRs on aircraft design

Prepared for 52nd Aerospace Sciences Meeting - January 2014

Aircraft Design with Electric Propulsion

Impact of Advanced Energy Technologies on Aircraft Design

Robert A. McDonald, California Polytechnic State University

Chapter DOI: 10.2514/6.2014-0538

Publication Date: 13-17 January 2014

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SAN LUIS OBISPO

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HALE UAV " … with multi-year endurance is conceptualized …"

Impact of Advanced Energy Technologies on Aircraft Design

Robert A. McDonald ; Adam T. Chase‡ Clayton Green‡ and Michael J. Waddington§
California Polytechnic State University, San Luis Obispo, California, 93407

The impact of low energy nuclear reaction (LENR) technology on the design of aircraft is examined. Energy conversion possibilities considered and a Brayton cycle engine with an LENR heat exchanger is selected. Potential aerospace applications of LENR devices are discussed and a high altitude long endurance (HALE) unmanned aerial vehicle with multi-year endurance is conceptualized with primary focus on energy management.

I. Introduction

Low energy nuclear reactions are a potentially revolutionary area of study in physics. Popularized in recent years by Allan Widom and Lewis Larsen, LENR are a radiation-free source of nuclear energy based on ultra-low momentum neutron catalyzed neutron reactions.[1] On metallic hydride surfaces, Widom and Larsen contend that a chain reaction can occur in which these ultra-low momentum neutrons lead to reactions that produce considerable amounts of heat.

See: http://arc.aiaa.org/doi/abs/10.2514/6.2014-0538

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April 14, 2014: Google purchased Titan Aerospace (U.S.)

Acquires manufacturer of high attitude, long endurance solar drones

Image credit: Titan Aerospace/Associated Press

"Google to buy Titan Aerospace as web giants battle for air superiority"

"Internet giant to acquire startup that was courted by Facebook"

Alistair Barr and Reed Albergotti, *The Wall Street Journal*
Updated April 14, 2014 7:26 PM. EDT

URL: http://online.wsj.com/news/articles/SB10001424052702304117904579501701702936522

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April 14, 2014: Google purchased Titan Aerospace (U.S.)

Complements the passive balloon technology in Google's Project Loon

- ✓ Google's future goal is to provide universal, low-cost global access to the Internet from various types of aerial wireless transmitter/receiver platforms; Facebook is pursuing similar technology acquisition strategy to increase worldwide base of users
- ✓ While passive solar balloons require no ongoing power for propulsion and can carry substantial payloads, they are subject to vagaries of prevailing winds at altitude and cannot maintain fixed positions in the sky; while solar-powered high altitude drone aircraft have onboard propulsion and can actively control their airborne positions, intrinsically low energy density of solar power cells on aircraft surfaces dictates very much smaller payloads and severely limits propulsive thrust and transmitter power
- ✓ Development of LENR-based power and propulsion systems for high altitude drones *a la* work of McDonald *et al*. (2014) would leverage nuclear energy densities that are 10^6 times larger than chemical or solar power sources; enables revolutionary new UAV aircraft that could have multi-year endurance, large payload capacities, thrust, and transmitter power --- permits global coverage with much smaller aircraft numbers
- ✓ If Google and Facebook aim to connect ~1^+ billion people who are living in today's world with no local electrical power other than batteries carried in from elsewhere, they need to have a system that can provide on-ground users with adequate electric power; stationary LENR-based distributed generation systems would be ideal for this

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Key take-aways from this presentation

Vladimir Nabokov: "Revelation can be more perilous than revolution"

- ✓ Technologists at NASA, Boeing, and California Polytechnic have been investigating alluring possibility of using green low energy nuclear reactions (LENRs) to power future aircraft
- ✓ Large Japanese companies such as Mitsubishi Heavy Industries and Toyota, among others, have active R&D programs and patent filings in LENRs and are publishing some of their experimental results in peer-reviewed science and engineering journals. It appears likely that their ultimate goal is to replace the internal combustion engine; please see: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-toyota-confirms-mitsubishi-transmutation-of-cs-to-proct-31-2013
- ✓ After decades of inaction and benign neglect, incredibly cautious and conservative U.S. Dept. of Energy has belatedly recognized LENRs; it is now willing to entertain proposals for modest amounts of funding through its transformational technology breakthrough arm, ARPA-E; see: http://www.forbes.com/sites/jeffmcmahon/2014/01/04/doe-mentions-technology-behind-the-home-nuclear-reactor-in-funding-opportunity/
- ✓ LENRs could revolutionize the world as we know it today if the technology is successfully commercialized and scales-up to several hundred kWh from milliwatts today in laboratory devices; megawatt power outputs are only required for a small percentage of applications
- ✓ Widom-Larsen theory explains device physics behind LENRs; it is published and fully consistent with a large body of peer-reviewed, published experimental data. Altogether, this implies that commercialization of the technology is possible and in fact likely. That said, non-trivial engineering lies between small, unreliable milliwatt laboratory devices of today and scaled-up high performance multi-kilowatt commercial products of tomorrow. Somebody or somebodies, somewhere, will eventually succeed --- Lattice will play a role in this process

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Commercializing a next-generation source of green nuclear energy

"The only thing that we can be sure of the future is that
it will be absolutely fantastic.

So, if what I say now seems to you to be very reasonable,
then I will have failed completely.

Only if what I tell you appears absolutely unbelievable
have we any chance
of visualizing the future as it really will happen."

Arthur C. Clarke (1964)

Image: National Geographic

Future predictions: Arthur C. Clarke predicting the future in 1964
YouTube video clip extracted from BBC's "Horizon" program (running time 3:12):
http://www.youtube.com/watch?feature=player_embedded&v=FxYgdX2PxyQ

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Contents

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LENRs are paradigm-shifting nuclear energy technology

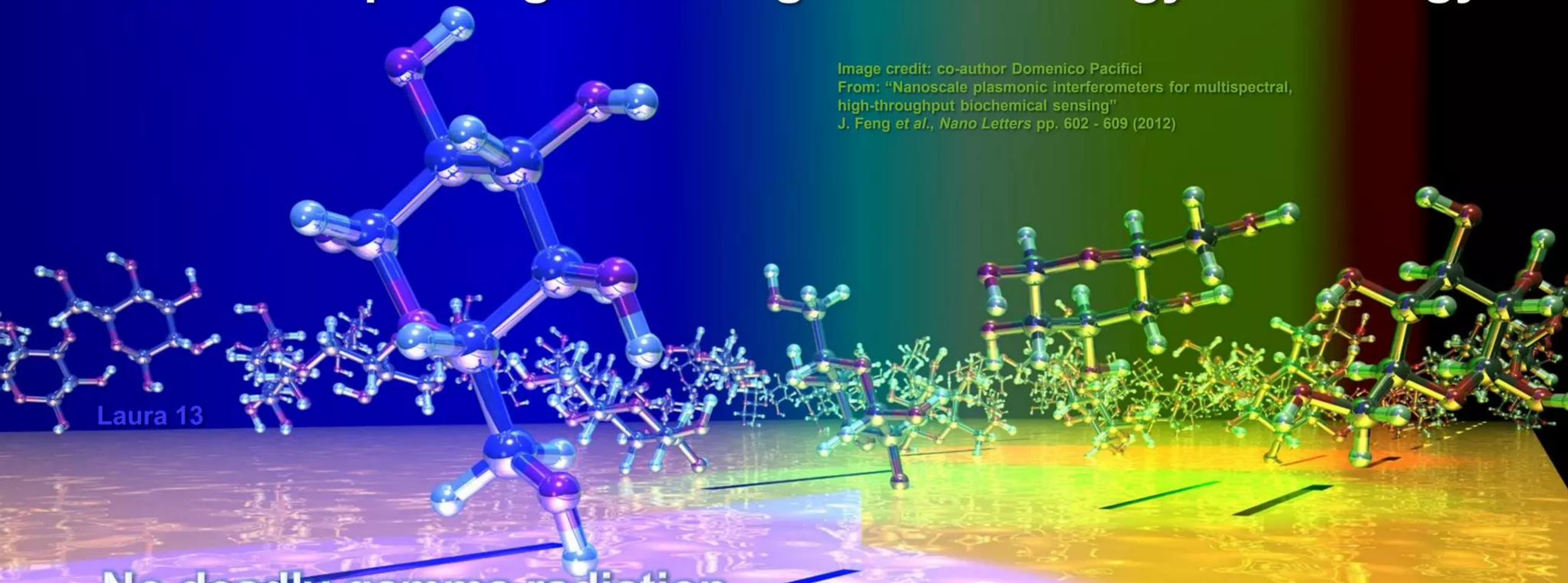

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng *et al.*, *Nano Letters* pp. 602 - 609 (2012)

Laura 13

No deadly gamma radiation ...

No dangerous energetic neutron fluxes and

Insignificant production of hazardous radwastes

Revolutionary, disruptive, and environmentally safe

Vast reduction in cost versus fission or fusion

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Nanotechnology and LENRs are mutually joined at the hip

Large length scales

What was formerly thought impossible becomes possible by utilizing applied nanotechnology

Nuclear-strength electric fields in μ-sized LENR-active sites enable $e + p$ reaction

Huge array of new technological possibilities and opportunities open-up at micron to nanometer length-scales

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Stars and physically gigantic reactors are unnecessary

Production with weak $e + p$ reaction creates safe low energy neutrons

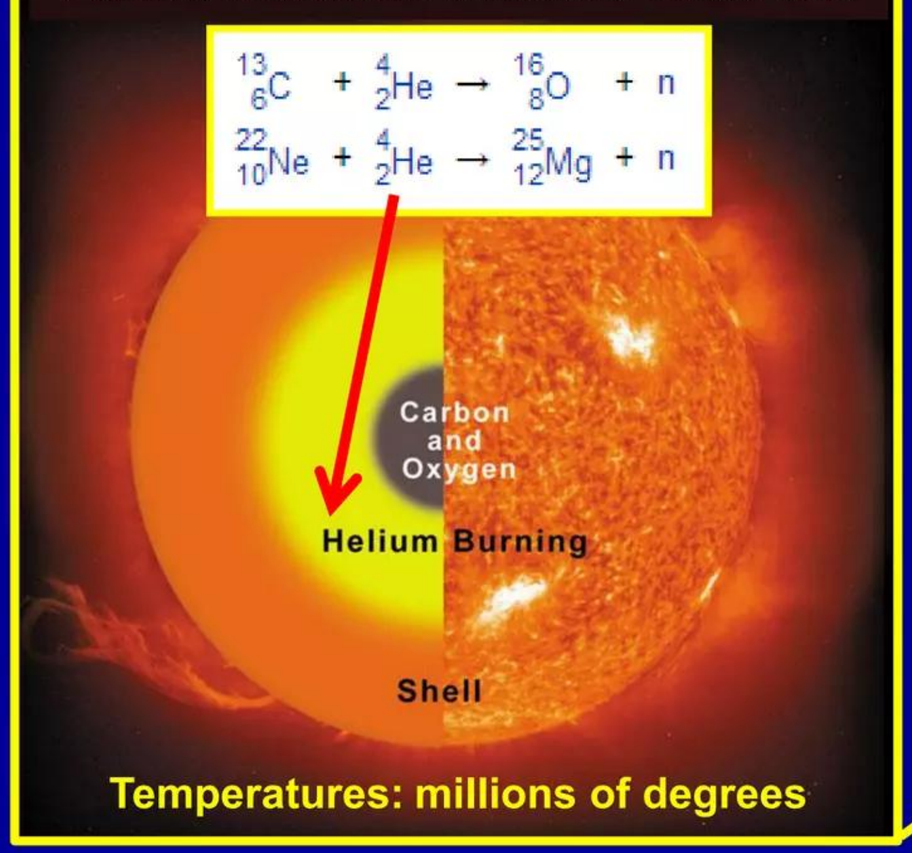
Ultra low energy neutrons are captured locally and do not escape reactors

All these fusion and LENR nuclear reactions seen below create neutrons (n):

Fusion reactions in a Red Giant star

$^{13}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + n$

$^{22}_{10}Ne + {}^{4}_{2}He \rightarrow {}^{25}_{12}Mg + n$



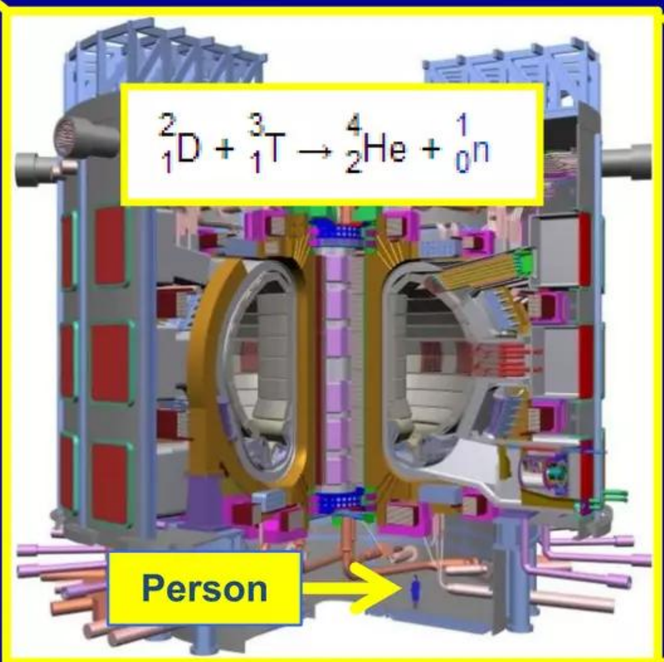
Temperatures: millions of degrees

Length-scale: millions of miles

Dangerous energetic 14.1 MeV neutrons

ITER: D+T fusion reactor

$^{2}_{1}D + {}^{3}_{1}T \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$



Length-scale: hundreds of feet

Temperatures: millions of degrees

These are safe!

LENR device

Length-scale: inches

Temperatures: thousands of degrees in microscopic regions

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LENRs increase safety and shrink size of nuclear power

Lack of hard radiation obviates need for shielding and containment

Opportunity to develop safe, battery-like portable LENR power sources

Fission reactors need 1 foot of steel and 3 feet of concrete to protect humans from hard radiation and wastes emitted by reactor; makes systems intrinsically large and heavy

LENRs enable devices something like this: small, portable battery-like power sources that are safe and disposable

Evolution of nuclear technology

Much larger LENR devices based on dusty plasma embodiments can potentially scale-up to megawatts; akin to today's power plants

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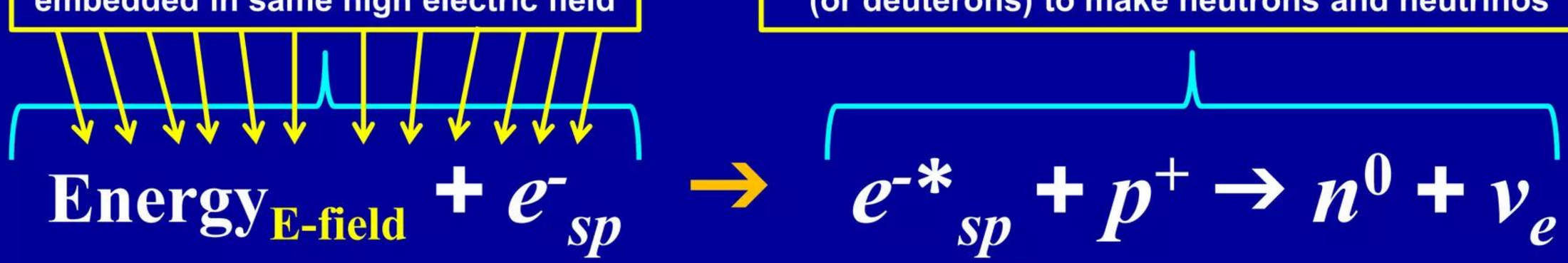
Basic reactions in Widom-Larsen theory are simple

Protons or deuterons react directly with electrons to make neutrons

Neutrons are then captured by other atoms → catalyze nuclear transmutations

Collective many-body quantum effects: many electrons each donate little bits of energy to a much smaller number of electrons that are also embedded in same high electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy from electric field can increase their effective masses ($m = E/c^2$) to point where they can react directly with protons (or deuterons) to make neutrons and neutrinos



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

Neutron-capture-catalyzed transmutations release energy stored in atoms:

Neutrons + atomic nuclei → heavier elements + decay products

Releases vast amounts of stored nuclear binding energy as energetic particles/photons that create heat

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Nuclear energy density is major competitive advantage

LENRs occupy sweet spot between fission and chemical power sources

Some LENRs release more energy than D+T fusion reactions

Less Energy Per Reaction

Reaction Type	Typical "Average" Energy Release		Relative Index of Energy Release	
U-235 Conventional Fission (1938)	220 MeV		1000	Fission-fusion
H+H Fusion in Stars (1939)	27 MeV	Nuclear: Strong Interaction	123	
D+T Fusion Reactors (1950s)	17. 6 MeV		80	
Light and Heavy Water LENRs (1989)	~ 22 MeV (high side)	Nuclear: Weak Interaction	91	LENRs
	~ 0.1 MeV (low side)		0.45	
Blacklight Power's "Hydrinos" (1991)	max 0.02 MeV	?	0.09	Chemical
Hydrogen Fuel Cells (1838)	0.0002 MeV	Chemical	0.0001	
Combustion of Gasoline (1876)	0.0001 MeV		0.00005	

Evolution of nuclear

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Nuclear energy density is major competitive advantage

Energy density of LENRs is ~5,000 times larger than that of gasoline

LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators	
Source of Energy	**Approximate Energy Density (Watt*hours/kg)**
Alkaline Battery	**164**
Lithium Battery	**329**
Zinc-Air Battery	**460**
Direct Methanol Fuel Cell (35% efficient)	**1,680**
Gas Burning Microgenerator (20% efficient)	**2,300**
100% Efficient Combustion of Pure Methanol	**5,930**
100% Efficient Combustion of Pure Gasoline	**11,500**
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)

Chemical Energy Sources

LENRs

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Nuclear energy density is major competitive advantage

Lithium LENR target fuel cycle releases more energy than D+T fusion

No dangerous radiation emitted by Li cycle; already demonstrated in laboratory

Widom & Larsen's 2006 *European Physical Journal C* paper shows the following Lithium-seed LENR network cycle:

Lithium-6 + 2 ULM neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value = 26.9 MeV

This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although a portion of the 26.9 MeV in excess nuclear binding energy released is lost (haircut) with emitted neutrinos, much of it still remains in the kinetic energy of the two helium atoms (which are low-energy alpha particles), and much more energetic beta particle.

In this particular case, local solid matter is heated-up by the scattering of low-energy alpha and much-higher-energy beta particles; heavy-mass electrons also present in LENR-active patches convert any locally produced hard gammas or X-rays (from whatever process) directly into infrared heat.

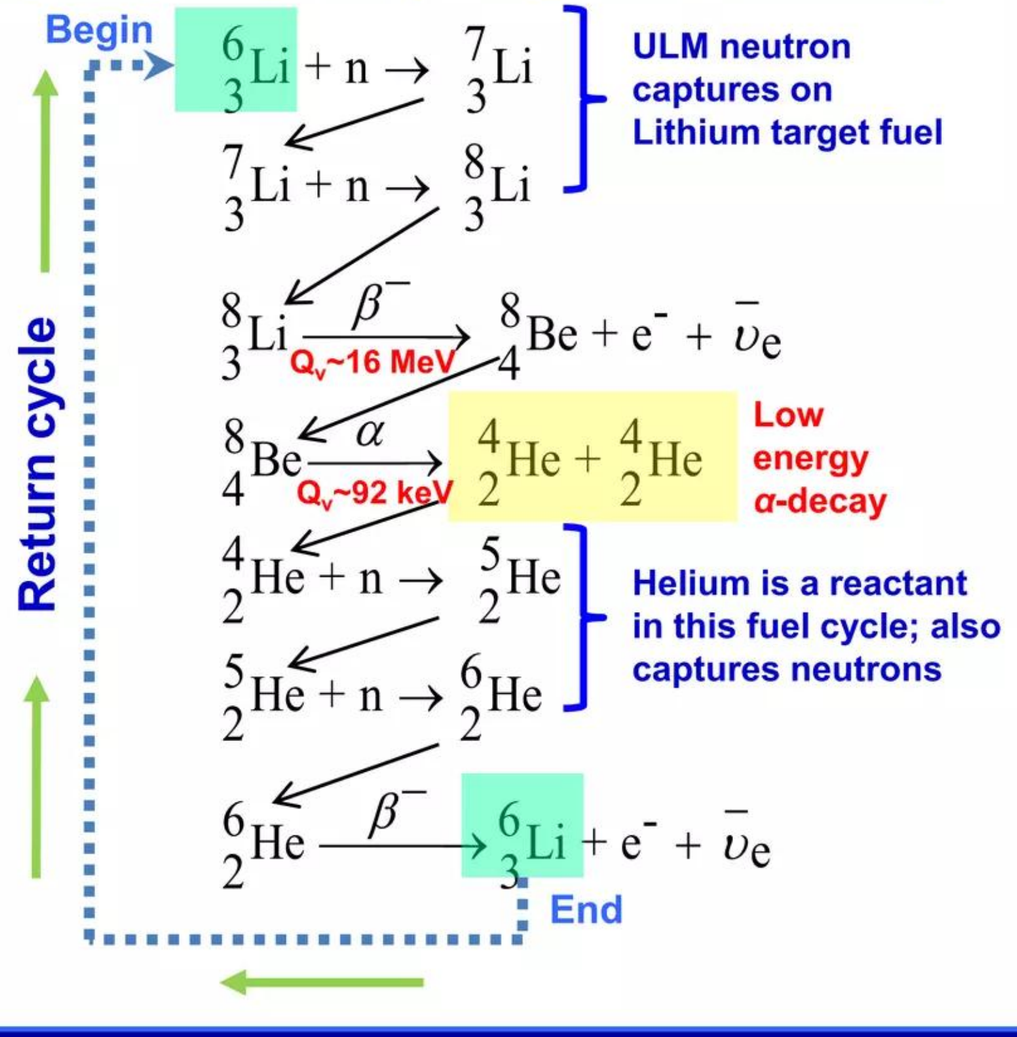
See: "Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" A. Widom and L. Larsen
European Physical Journal C – Particles and Fields 46 pp. 107-111 (2006)

ULMN-catalyzed LENR Lithium network cycle – from Eqs. 30 - 32

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

LENR neutron-catalyzed Lithium fuel cycle

^{8}Li β-decay is largest single energy release in LENR Li cycle



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Nuclear energy density is major competitive advantage

Calculations illustrate potential for use in compact power sources

LENR system thermal output can be up to 34x input energy using Lithium fuel

- ✓ To simplify calculations, we will assume that conversion of input energy (in this case, an electric current) into energy available to produce LENR ULM neutrons is 100 percent efficient in order to estimate a theoretical upper bound on potential energy releases from a compact LENR heat source; will also assume that 100 percent of the ULM neutrons produced in the hypothetical device are absorbed locally (a pretty safe bet that is supported by 20^{+} years of experiments) and that they are only absorbed by a target fuel comprising isotopically pure Lithium-6, resulting in a series of nuclear reactions beginning with Lithium-6 and ending with Helium-4. Lastly, we will assume that the base fuel used to produce LENR ULM neutrons in our hypothetical device is deuterium and that it has an LENR-active working surface area of 1 cm^2

- ✓ Input energy required to produce 1 neutron/cm^2/sec from deuterium base fuel to react with the Lithium-6 target fuel is 0.39 MeV per neutron. However, we need two ULM neutrons to complete the entire series of reactions, so the required total input energy to the device is 0.78 MeV/cm^2/sec. The net energy release from that particular series of LENR reactions starting with Lithium-6 is 26.9 MeV/cm2/sec = 4.28 x 10^{-12} J/cm^2/sec (1 eV = 1.602 x 10^{-19} J); 26.9 MeV thus represents a theoretical maximum upper bound of ~ 34x total input power in case of Lithium fuel targets

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Nuclear energy density is major competitive advantage

Calculations illustrate its potential for use in compact power sources

Neutron flux of 1 x 10^{12} cm^2/sec predicts heat output seen in some lab devices

- ✓ As there are ~ 10^{14} of these 26.9 MeV energy releases taking place per second on the 1 cm^2 LENR device, the total energy release is 4.28 x 10^{-12} J/cm^2/sec x 10^{14} = 428 J/cm^2/sec. This represents 428 W/cm^2, a large device-level power density. At a lesser ULM neutron production rate of 1 x 10^{12} cm^2/sec, the overall energy production rate would drop down to 4.28 J/cm^2/sec or 4.28 W/cm^2. At a ULM neutron production rate of 1 x 10^{11} cm^2/sec, the energy production rate would drop down to 0.428 J/cm^2/sec or 0.428 W/cm^2, which is close to levels of excess heat output that are often observed in the limited subset of electrolytic LENR experiments that researchers deem successful at making excess heat

- ✓ In this particular example, a heat generating rate of 428 W/cm^2 means 0.428 kWh/cm^2 produced in an hour for a Lithium-6-fueled 1 cm^2 LENR device, without releasing any CO_2. In comparison to minuscule nanogram (10^{-9} g) quantities of LENR reactants consumed, the complete combustion of 1 US gallon of gasoline (weighing 2.7 kg) with O_2 generates ~33.56 kWh of heat energy and releases ~8.8 kg of CO_2 into the atmosphere. Scaling up surface area of the idealized LENR device 1,000 fold could generate 428 kWh, while a 1 m^2 device would create a 4.28 Megawatt eco-green nuclear power source

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Nuclear energy density is major competitive advantage

LENRs enable development of safe portable nuclear power sources

- ✓ Advanced batteries are just beginning to approach their technological limits in terms of achievable energy densities; >100x energy density increase is unlikely using chemical power
- ✓ Lithium-based batteries could unknowingly be encountering LENRs already; subset of "field failure" thermal runaways could potentially be triggered by rare LENR hotspots inside batteries
- ✓ Lithium-based batteries effectively store electrical energy in electrons in ions at only eV energies; a LENR Lithium fuel cycle releases ~27 MeV per nuclear reaction cycle (~27 million x more)
- ✓ Since they are radiation-free and do not produce long-lived radioactive isotopes, battery-like LENR power generation devices would not require any radiation shielding or containment subsystems, dramatically reducing their weight, size, and cost; enable development of revolutionary portable, battery-like nuclear power systems for compact electronics
- ✓ With energy densities >1 million x those of chemical systems, compact, portable LENR-based generators could eventually compete directly with batteries and fuel cells in key applications

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Nuclear energy density is major competitive advantage

LENRs enable development of a safe portable nuclear power source

Battery-like LENRs akin to betavoltaics but much higher energy density

Unlike betavoltaics, LENRs need input energy and can be turned on/off

Betavoltaic batteries directly harvest energetic electrons produced by unstable beta-decaying isotopes; radioisotope thermal generators (RTGs) based on variety of different isotopes harvest heat - subsystem converts it into electricity

Raytheon

Type	Power (mW)	Total Energy (mWh)	Volume (cm^3)	Weight (g)	Total Energy Density (mWh/g)
Lithium AA Battery	~1 (1.5 V)	4,350	7.9	14.5	300
Betavoltaic 1 cm^2	~0.3 (2 V)	10,512	0.025	0.08	131,400

Table 1. Comparison of a lithium AA battery with conceptual betavoltaic power source. Source: M.V.S Chandrashekhar, et al., "Design and Fabrication of a 4H SiC Betavoltaic Cell," Cornell University.

Raytheon

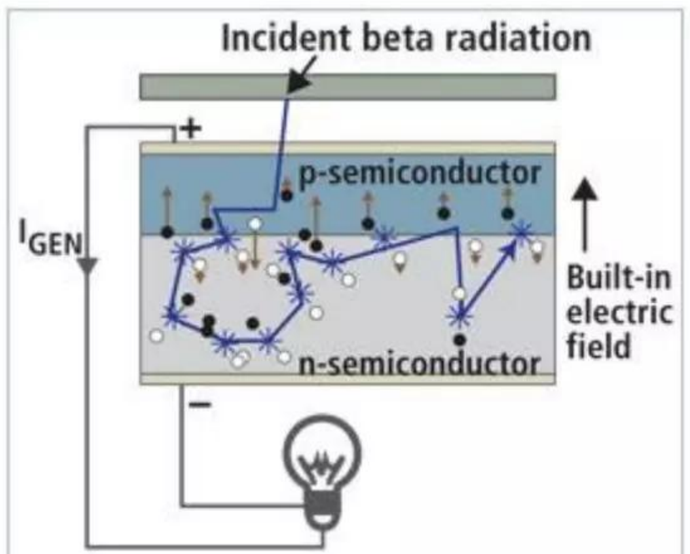

Figure 2. Schematic betavoltaics P-N junction power source. One betavoltaic conceptual design configuration is based on "direct conversion" that derives small currents from electron-hole pairs produced by impinging beta rays in P-N junction depletion zones.

Article titled "Power sources that last a century" at: http://www.raytheon.com/newsroom/technology_today/2011_i1/power.html

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LENRs may enable vast increases in system performance

Scale-up LENR system power outputs and integrate energy conversion

- ✓ **LENRs can presently reach temperatures of 4,000 - 6,000° K and boil refractory metals in limited numbers of microscopic LENR-active hot spot sites on laboratory device surfaces.** Lattice plans to use its unique proprietary knowledge of LENR engineering physics and key operating parameters (e.g., achieving and maintaining very high local surface electric fields) to first get heat production working well microscopically. That is: reproducibly trigger LENRs on specific, purpose-designed nanoparticulate structures with dimensions ranging from nanometers to microns that are fabricated using existing, off-the-shelf nanotech processes and then deliberately emplaced at what will become LENR-active sites located on Hydrogen-loaded substrate surfaces
- ✓ **In principle, output of such LENR heat sources could be readily scaled-up:** either by fabricating larger area-densities of affixed nanostructures that facilitate formation of LENR hot spot sites on device surfaces, or by injecting larger quantities of specially designed fuel nanoparticles into volumetrically larger reaction chambers containing turbulent dusty plasmas, with or without spatially organized magnetic fields present
- ✓ **A variety of off-the-shelf energy conversion subsystems could potentially be integrated with commercial versions of LENR-based heat sources. These include: thermoelectrics or thermionics; steam engines; Rankine cycle steam turbines; Brayton cycle gas turbines, boilers, etc.** Other more speculative possibilities involve new types of direct energy conversion technologies that are still under development

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Low Energy Neutron Reactions or LENRs

Truly green nuclear process: no deadly radiation or long-lived wastes

Hidden in plain sight for 100 years because hard radiation is absent

2014: device physics sufficiently understood to begin commercialization

1945

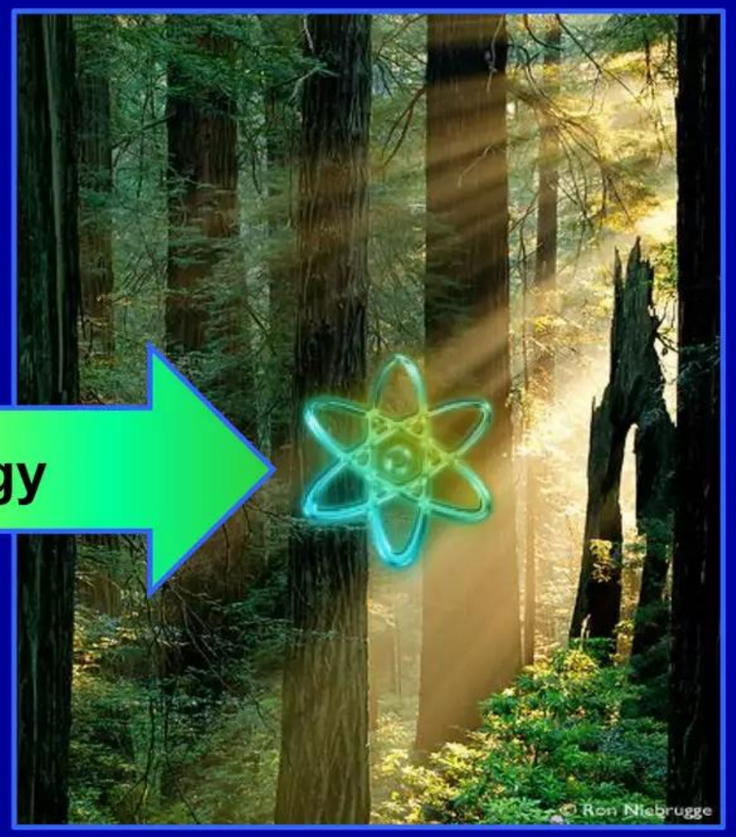
2005

Widom-Larsen theory of LENRs is developed

Evolution of nuclear technology

LENRs are safe and benignly green

2014



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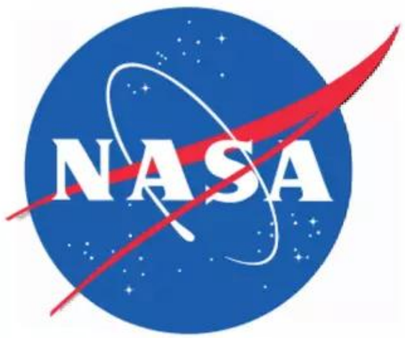
NASA/CR-2012-217556 report dated May 2012

Specifics of previously cited recent NASA document are uncertain

Might be related to an earlier contract first revealed in May 2012

NASA/CR-2012-217556



Subsonic Ultra Green Aircraft Research
Phase II: N+4 Advanced Concept Development

Marty K. Bradley and Christopher K. Droney
Boeing Research and Technology, Huntington Beach, California

Source of document for screen-capture images: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120009038_2012008934.pdf

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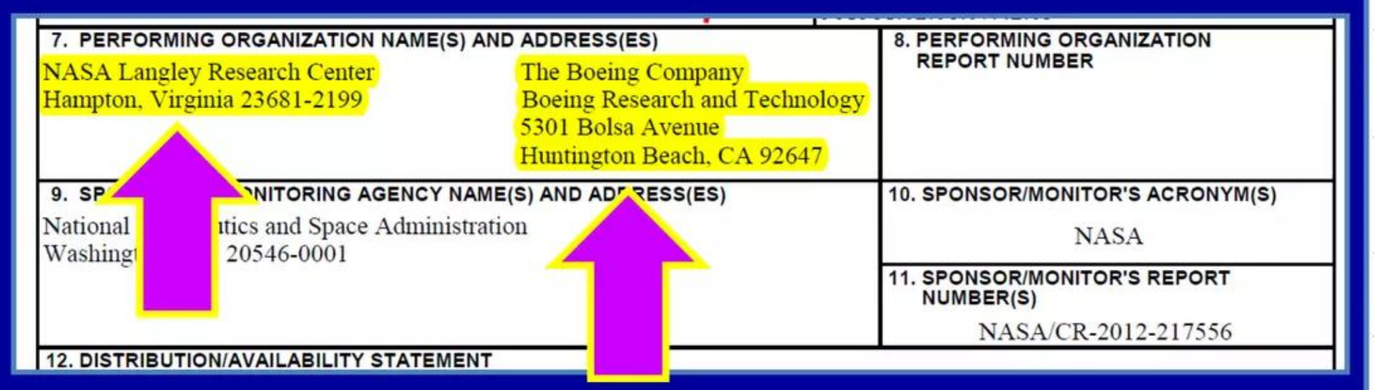
Contract NASA/CR-2012-217556

Found on final page A-11 of report document

Documents that NASA and Boeing are performing together on this particular contract



7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA Langley Research Center
Hampton, Virginia 23681-2199

The Boeing Company
Boeing Research and Technology
5301 Bolsa Avenue
Huntington Beach, CA 92647

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SP…NITORING AGENCY NAME(S) AND AD…RESS(ES)

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Washing… 20546-0001

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NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

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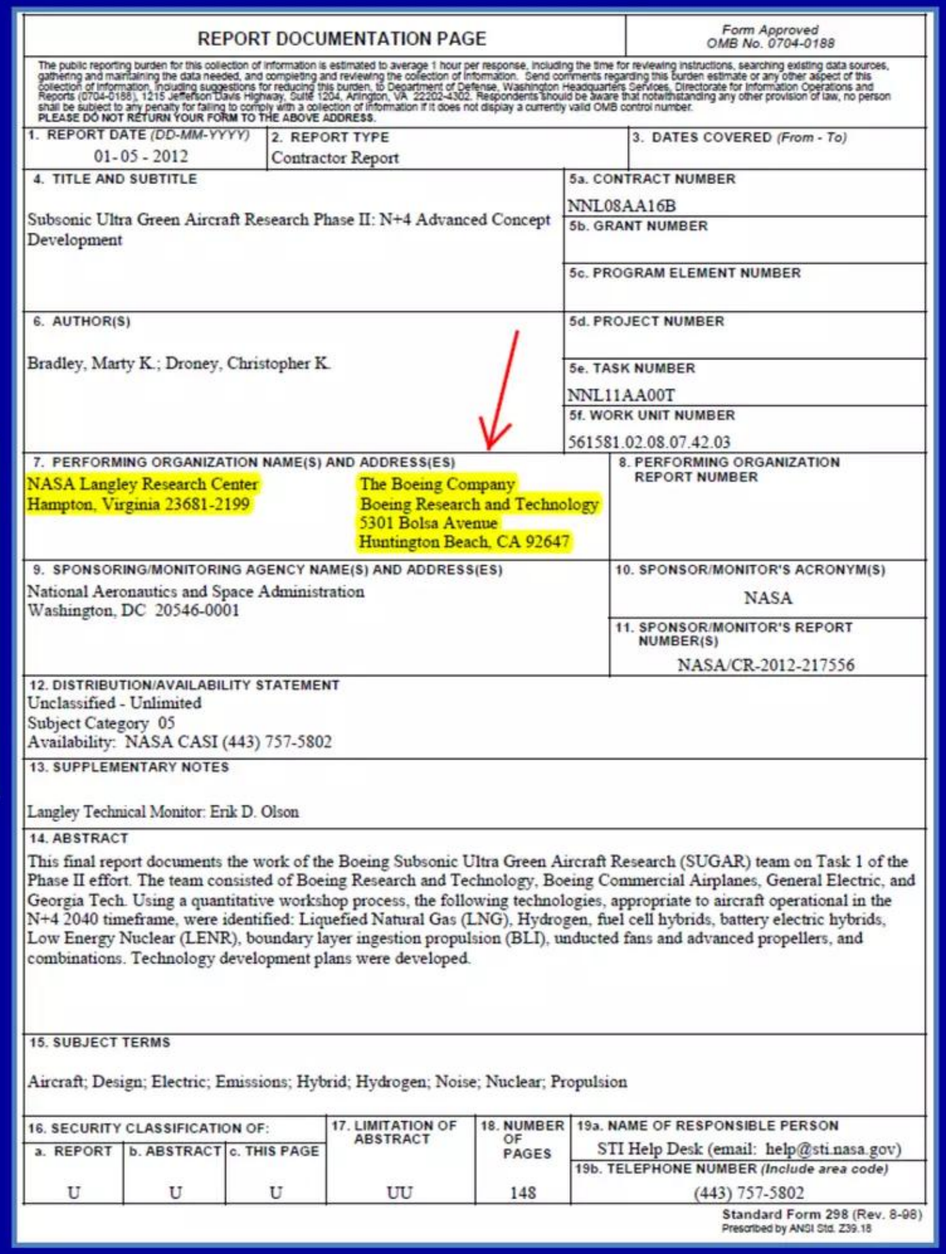
12. DISTRIBUTION/AVAILABILITY STATEMENT

Boeing's contract team works for the Advanced Network & Space Systems Group which operates out of a large 50 year-old R&D facility located in Huntington Beach, CA



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The Boeing Company
Boeing Research and Technology
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Langley Technical Monitor: Erik D. Olson

14. ABSTRACT
This final report documents the work of the Boeing Subsonic Ultra Green Aircraft Research (SUGAR) team on Task 1 of the Phase II effort. The team consisted of Boeing Research and Technology, Boeing Commercial Airplanes, General Electric, and Georgia Tech. Using a quantitative workshop process, the following technologies, appropriate to aircraft operational in the N+4 2040 timeframe, were identified: Liquefied Natural Gas (LNG), Hydrogen, fuel cell hybrids, battery electric hybrids, Low Energy Nuclear (LENR), boundary layer ingestion propulsion (BLI), unducted fans and advanced propellers, and combinations. Technology development plans were developed.

15. SUBJECT TERMS
Aircraft; Design; Electric; Emissions; Hybrid; Hydrogen; Noise; Nuclear; Propulsion

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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Found on page i of report document

"Following technologies were identified: … Low Energy Nuclear (LENR), …"

NASA Contract NNL08AA16B – NNL11AA00T – Subsonic Ultra Green Aircraft Research – Phase II
N+4 Advanced Concept Development

Abstract

This final report documents the work of the Boeing Subsonic Ultra Green Aircraft Research (SUGAR) team on Task 1 of the Phase II effort. The team consisted of Boeing Research and Technology, Boeing Commercial Airplanes, General Electric, and Georgia Tech.

Using a quantitative workshop process, the following technologies, appropriate to aircraft operational in the N+4 2040 timeframe, were identified: Liquefied Natural Gas (LNG), Hydrogen, fuel cell hybrids, battery electric hybrids, Low Energy Nuclear (LENR), boundary layer ingestion propulsion (BLI), unducted fans and advanced propellers, and combinations. Technology development plans were developed.

The team generated a series of configurations with different combinations of some of these technologies. The higher heating value of LNG reduces the weight of fuel burned, but because of heavier aircraft systems, more energy is used for a given flight. LNG fueled aircraft have the potential for significant emissions advantages and LNG enhances the integration of fuel cells into the aircraft propulsion and power system.

An unducted fan increases propulsive efficiency and reduces fuel burn. Adding a fuel cell and electric motor into the propulsion system also leads to improvements in emissions and fuel burn. An aft fuselage boundary layer propulsor also resulted in a fuel burn benefit.

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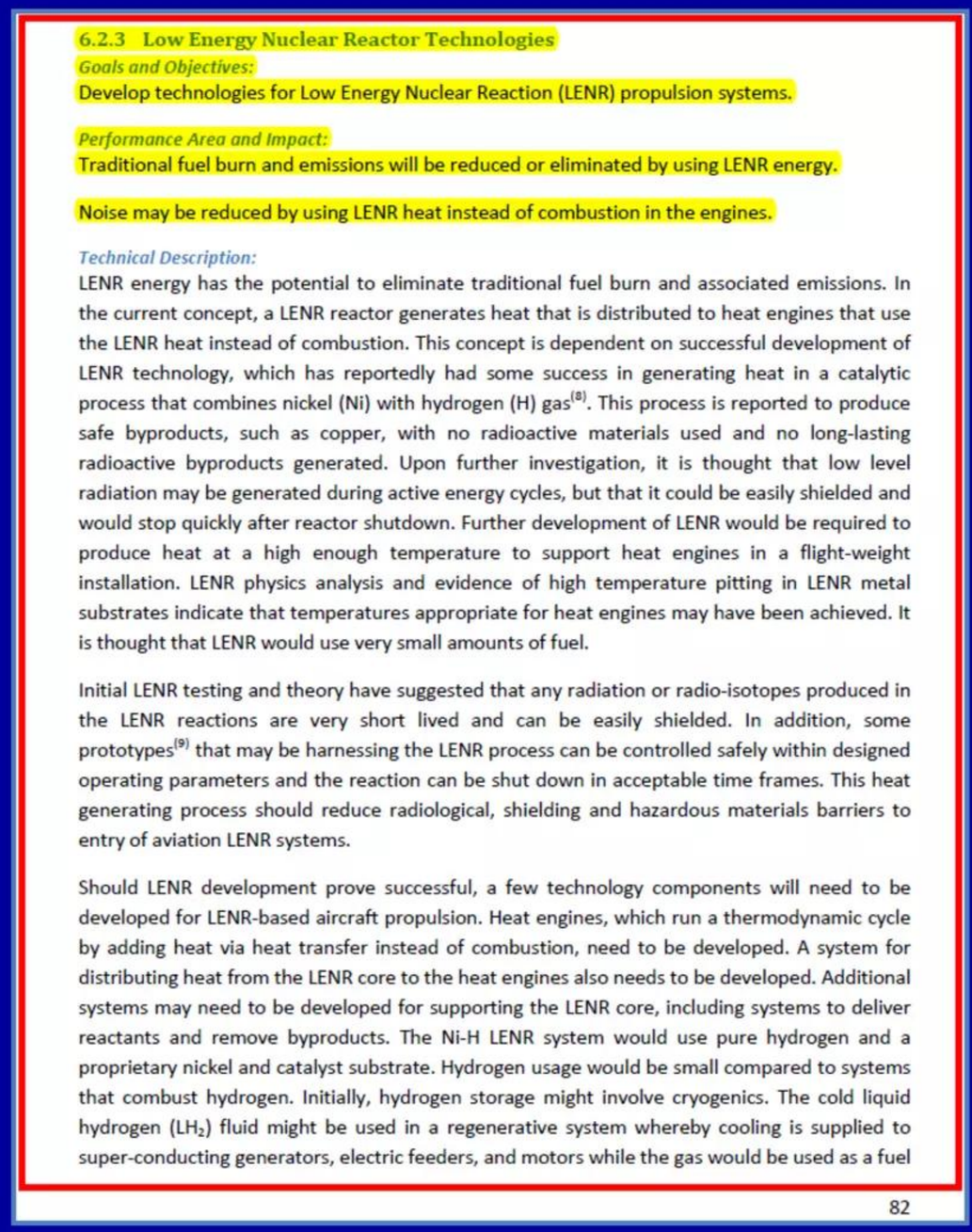
Quoting: "Initial LENR testing and theory have suggested that any radiation or radio-isotopes produced in the LENR reactions are very short lived and can be easily shielded. In addition, some prototypes that may be harnessing the LENR process can be controlled safely within designed operating parameters and the reaction can be shut down in acceptable time frames. This heat generating process should reduce radiological, shielding and hazardous materials barriers to entry of aviation LENR systems."

A copy of this contract report document annotated by Lattice to highlight key sections relevant to LENRs is available:

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-report-reveals-boeing-and-nasa-investigating-lenrpowered-aircraftaug-3-2012



6.2.3 Low Energy Nuclear Reactor Technologies

Goals and Objectives:

Develop technologies for Low Energy Nuclear Reaction (LENR) propulsion systems.

Performance Area and Impact:

Traditional fuel burn and emissions will be reduced or eliminated by using LENR energy.

Noise may be reduced by using LENR heat instead of combustion in the engines.

Technical Description:

LENR energy has the potential to eliminate traditional fuel burn and associated emissions. In the current concept, a LENR reactor generates heat that is distributed to heat engines that use the LENR heat instead of combustion. This concept is dependent on successful development of LENR technology, which has reportedly had some success in generating heat in a catalytic process that combines nickel (Ni) with hydrogen (H) gas[8]. This process is reported to produce safe byproducts, such as copper, with no radioactive materials used and no long-lasting radioactive byproducts generated. Upon further investigation, it is thought that low level radiation may be generated during active energy cycles, but that it could be easily shielded and would stop quickly after reactor shutdown. Further development of LENR would be required to produce heat at a high enough temperature to support heat engines in a flight-weight installation. LENR physics analysis and evidence of high temperature pitting in LENR metal substrates indicate that temperatures appropriate for heat engines may have been achieved. It is thought that LENR would use very small amounts of fuel.

Initial LENR testing and theory have suggested that any radiation or radio-isotopes produced in the LENR reactions are very short lived and can be easily shielded. In addition, some prototypes[9] that may be harnessing the LENR process can be controlled safely within designed operating parameters and the reaction can be shut down in acceptable time frames. This heat generating process should reduce radiological, shielding and hazardous materials barriers to entry of aviation LENR systems.

Should LENR development prove successful, a few technology components will need to be developed for LENR-based aircraft propulsion. Heat engines, which run a thermodynamic cycle by adding heat via heat transfer instead of combustion, need to be developed. A system for distributing heat from the LENR core to the heat engines also needs to be developed. Additional systems may need to be developed for supporting the LENR core, including systems to deliver reactants and remove byproducts. The Ni-H LENR system would use pure hydrogen and a proprietary nickel and catalyst substrate. Hydrogen usage would be small compared to systems that combust hydrogen. Initially, hydrogen storage might involve cryogenics. The cold liquid hydrogen (LH_2) fluid might be used in a regenerative system whereby cooling is supplied to super-conducting generators, electric feeders, and motors while the gas would be used as a fuel

82

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"Widom-Larson theory appears to have the best current understanding."

in the LENR reactor. The primary LENR byproducts that would require periodic removal from the aircraft are the catalyst and nickel that are contained within the reactor core. Through thoughtful design of the reactor core, preliminary information suggests that these can be easily removed and replaced. The reactor core might then be recycled at low cost, due to the absence of toxic products in the core.

Technology Status:

Multiple coherent theories that explain LENR exist which use the standard Quantum Electrodynamics & Quantum Chromodynamics model. The Widom-Larson[10] theory appears to have the best current understanding, but it is far from being fully validated and applied to current prototype testing. Limited testing is ongoing by NASA and private contractors of nickel-hydrogen LENR systems. Two commercial companies (Leonardo Corp. & Defkalion) are reported to be offering commercial LENR systems. Those systems are advertised to run for 6 months with a single fueling cycle. Although data exists on all of these systems, the current data in each case is lacking in either definition or 3rd party verification. Thus, the current TRL assessment is low.

In this study the SUGAR Team has assumed, for the purposes of technology planning and establishing system requirements that the LENR technology will work. We have not conducted an independent technology feasibility assessment. The technology plan contained in this section merely identifies the steps that would need to take place to develop a propulsion system for aviation that utilizes LENR technology.

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Contract NASA/CR-2012-217556

Table 7.1 found on page 120 of report document

NASA Contract NNL08AA16B – NNL11AA00T – Subsonic Ultra Green Aircraft Research – Phase II
N+4 Advanced Concept Development

A summary of the technologies investigated in this study is shown in Table 7.1.

Table 7.1 – Task 1 Technology Summary

Technology	Impact	Goals	Relationships	Major Concerns
LNG	Very Significant	Fuel Burn, Emissions, (Fuel Cost), (Fuel Supply)	Enabling to Fuel Cells and Low Emission Combustors	Methane Emissions, Safety, Infrastructure
Unducted Fan	Very Significant	Fuel Burn	Enhancing	Noise, Safety
Engine Fuel Cell	Significant	Fuel Burn, Emissions	Enhancing, Dependent on LNG or Hydrogen	
BLI Aft Propulsor	Significant	Fuel Burn, Emissions, Noise	Enhancing, Dependent on power source (fuel cell or batteries) for electric motor	
LENR	Game Changing	Fuel Burn, Energy Use, Emissions, Noise	Dependent on Hybrid Technology (gas turbine or electric hybrid)	Feasibility, Safety, Weight, Customer Acceptance
Hydrogen	Very Significant	Fuel Burn, Emissions	Enabling to Fuel Cells and Low Emission Combustors, Dependent on Production Technology	Low Cost Green Production, Safety, Customer Acceptance, Infrastructure

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"LENR technology is potentially game-changing"

LNG technologies should continue to be investigated as there are significant potential emissions advantages, as well as advantages in cost and energy availability. However adding LNG to the aviation propellant infrastructure would be a significant challenge. Also, active research into methane leakage during natural gas extraction, processing, storage, and use should be monitored, as this could have an additional negative environmental impact.

Unducted fans, fuel cells, and BLI are potential enhancing technologies that offer significant improvements.

LENR technology is potentially game-changing to not just aviation, but the worldwide energy mix as well. This technology should be followed to determine feasibility and potential performance.

Hydrogen technology also has potential benefits, but widespread aviation use of hydrogen requires large infrastructure changes as well as significant improvements to produce hydrogen in a low cost environmentally friendly process.

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Figure 5.19 found on page 39 of report document

Subsonic Ultra Green Aircraft Research (SUGAR) Volt future aircraft design

PROJECTED CHARACTERISTICS			
	WING TOTAL	V-TAIL TRAP	H-TAIL TRAP
AREA (SQ. FT)	1477.11	257.76	265.89
ASPECT RATIO	19.55	1.00	5.00
SPAN (INCHES)	2039.30	192.66	437.54
TAPER RATIO	0.35	1.00	0.35
MAC (INCHES)	110.29	192.66	94.27
DIHEDRAL (DEG.)	-1.50	--	-3.00
¼ CHORD SWEEP (DEG.)	12.52	41.00	25.30
ROOT CHORD (INCHES)	130.31	192.66	129.64
TIP CHORD (INCHES)	45.13	192.66	45.37
TAIL VOLUME COEFFICIENT	--	0.07	1.57

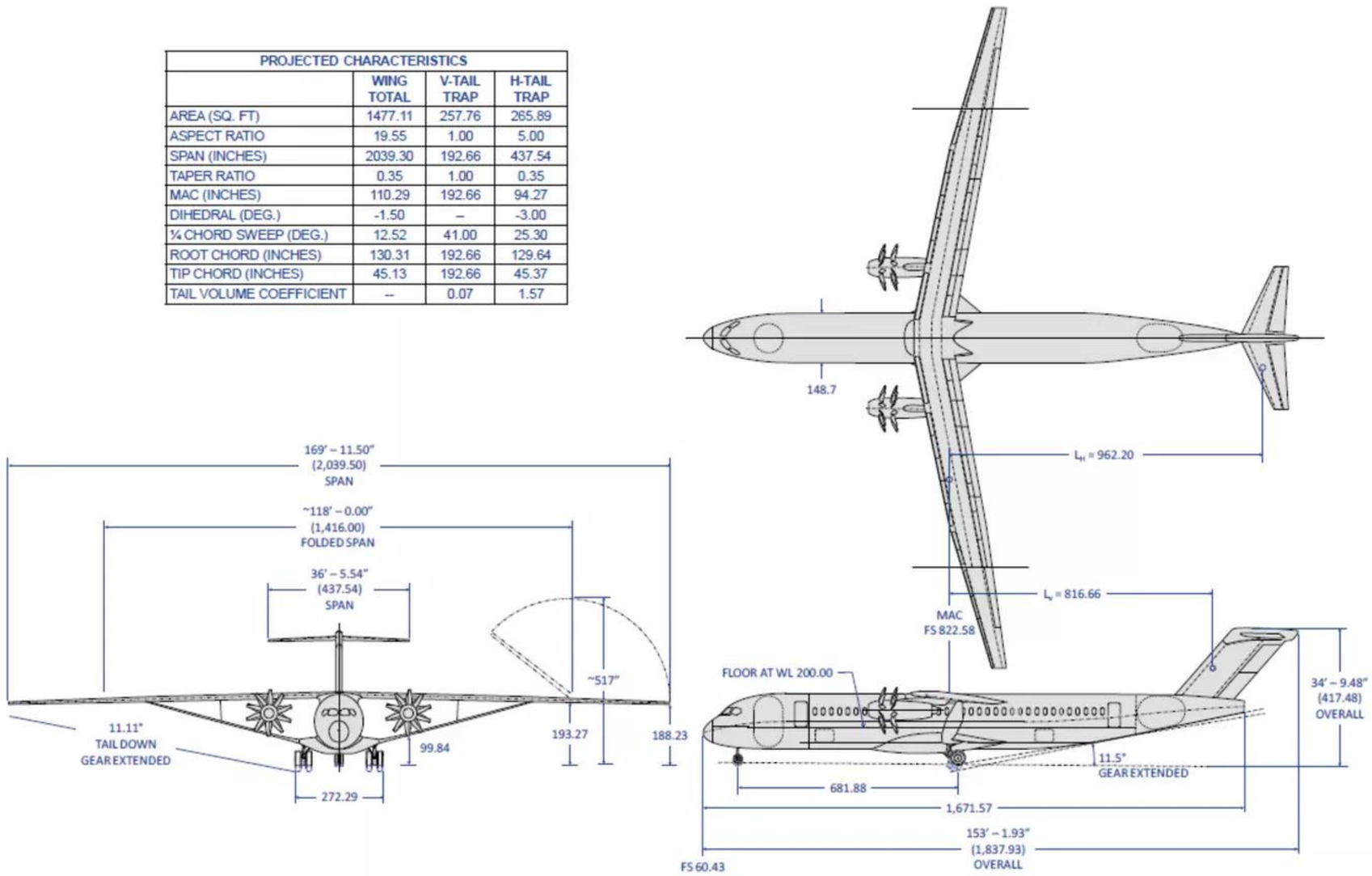

Figure 5.19 – 765-095-TS3 - Truss Braced Wing With LNG UDF

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Future aircraft could potentially be powered by LENRs

Megawatts are required to provide propulsion for large civilian aircraft

LENRs are world changing if systems just scale-up to several hundred kilowatts

- ✓ Total power required to propel a large future subsonic aircraft as depicted in the NASA/Boeing image to right measured in tens of megawatts (MW)
- ✓ For example, a modern General Electric GE90 fanjet system that powers large Boeing 777s (there are two such engines per plane) puts out roughly 160,000 horsepower or ~117MW (smallish coal-fired power plant has peak electrical output of ~500 - 600 MW)
- ✓ NASA and Boeing clearly believe that LENRs can potentially scale-up total system power outputs into the 50 - 100 MW range which can power big planes
- ✓ Interestingly, scale-up to megawatts is not really mandatory to radically change the world as it exists today; if it turned out that LENR systems could only be scaled-up to several hundred kilowatts (kWh) the impact on global society would still be revolutionary

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Energy density of LENR fuels is revolutionary for aircraft

Roughly 5,000 times more energy-dense than any gasoline or jet fuels

Fuel for Lockheed Martin SR-71 mission could likely fit in two FedEx boxes

SR-71 Blackbird carried ~12,000 gallons of JP-7 aviation fuel with full tanks; permitted unrefueled range of about 3,250 miles traveling at Mach 3.0

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All-electric general aviation e-aircraft are already upon us

Yuneec e430 (China) carries two adult passengers in comfort

Lattice Energy LLC

All-electric general aviation e-aircraft are already upon us

Schematic drawing showing various views of Yuneec e430 (China)

Plane looks graceful and has an aerodynamically efficient design

Lattice Energy LLC

All-electric general aviation e-aircraft are already upon us

Selected information about the Yuneec e430 (China)

Lithium-ion battery pack only stores 18 kWh

Product	Yuneec e-430 General Aviation Aircraft (China)
Approx. price (US$)	Rumored to be ~90,000
No. of passengers	2
Battery type; motor	Chinese manufactured Lithium-ion; 40 hp electric
Battery capacity (kWh)	18 kWh
Range	Est. 150 miles at cruise speed of 60 mph
Endurance	2.5 hours
Status	Per Greenwing, supposedly going into production
Other	Not entirely clear if FAA certification is complete
Company website	http://yuneec.com/Aircraft.html

Lattice Energy LLC

All-electric general aviation e-aircraft are already upon us

New Airbus E-Fan 2.0 (Europe) carries two adult passengers

E-FAN

Technology demonstrator of an electrically-powered, all-composite general aviation training aircraft

Images credit: Airbus

Lattice Energy LLC

All-electric general aviation e-aircraft are already upon us

New Airbus E-Fan 2.0 (Europe) carries two adult passengers

Image credit: Airbus

E-FAN
BY AIRBUS GROUP

E-FAN TECHNICAL DATA

Wing span:	9.50 m
Length:	6.67 m
Empty weight:	500 kg
Lift/drag ratio:	16
Total engine power:	60 kiloWatt
Battery system:	120 cells (Lithium Polymer)
Battery rated capacity:	40 Ah per cell 4 Volt per cell
Endurance:	45 min – 1 hour
Take-off speed:	110 km/h
Cruise speed:	160 km/h
Max. speed:	220 km/h

Table: courtesy of Airbus

Image credit: Airbus

Lattice Energy LLC

All-electric general aviation e-aircraft are already upon us

Airbus E-Fan 2.0 carries two adult passengers

Lithium-ion battery pack only stores 19 kWh

http://www.france24.com/en/20140426-video-world-first-electric-plane-takes-off-france/

Product	Airbus E-Fan 2.0 Prototype Aircraft (Europe)
Approx. price (US$)	Not yet available
No. of passengers	2
Battery type; motor	Kokam 40Ah 4V Lithium-ion polymer; 40 hp electric (2)
Battery capacity (kWh)	~19.2 kWh (120 cells)
Range	Est. 100 miles at cruise speed of ~99 mph
Endurance	Roughly 1 hour (with present battery packs)
Status	First public test flight: Bordeaux, FR on April 25, 2014
Other	Planning to install higher-capacity batteries
Company website	http://www.airbus-group.com/airbusgroup/int/en/news/media.1dc1ec54-b7f0-4bbb-90c1-b67c713894d5.-E-Fan.html

Lattice Energy LLC

LENRs could enable all-electric drones like USA's Predator

Some view this iconic UAV as an infamous instrument of war

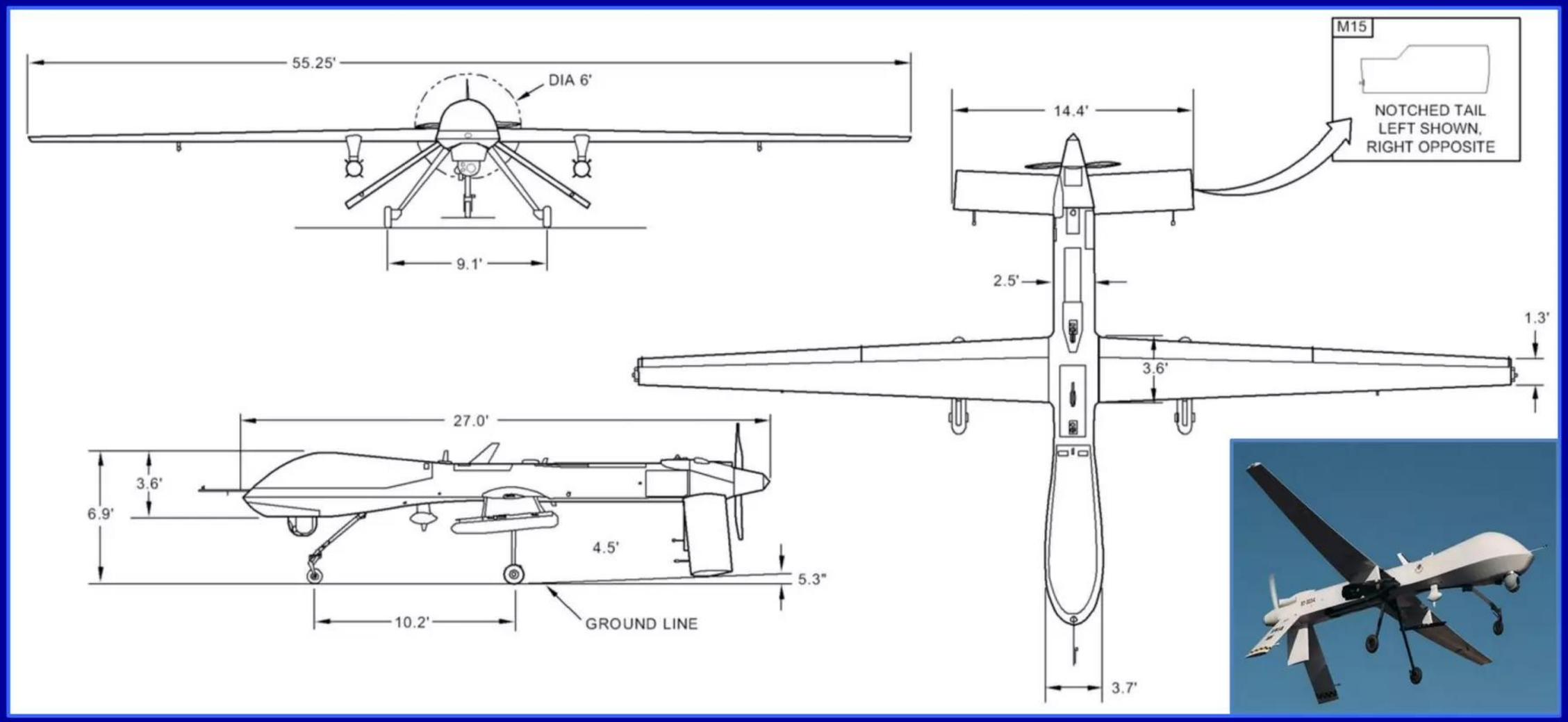
Drones also have many valuable peaceful civilian applications

Lattice Energy LLC

LENRs could enable all-electric drones like USA's Predator

Schematic dimensional drawing of the General Atomics MQ-1 Predator

Aircraft carries communications, sensors, and onboard weapons



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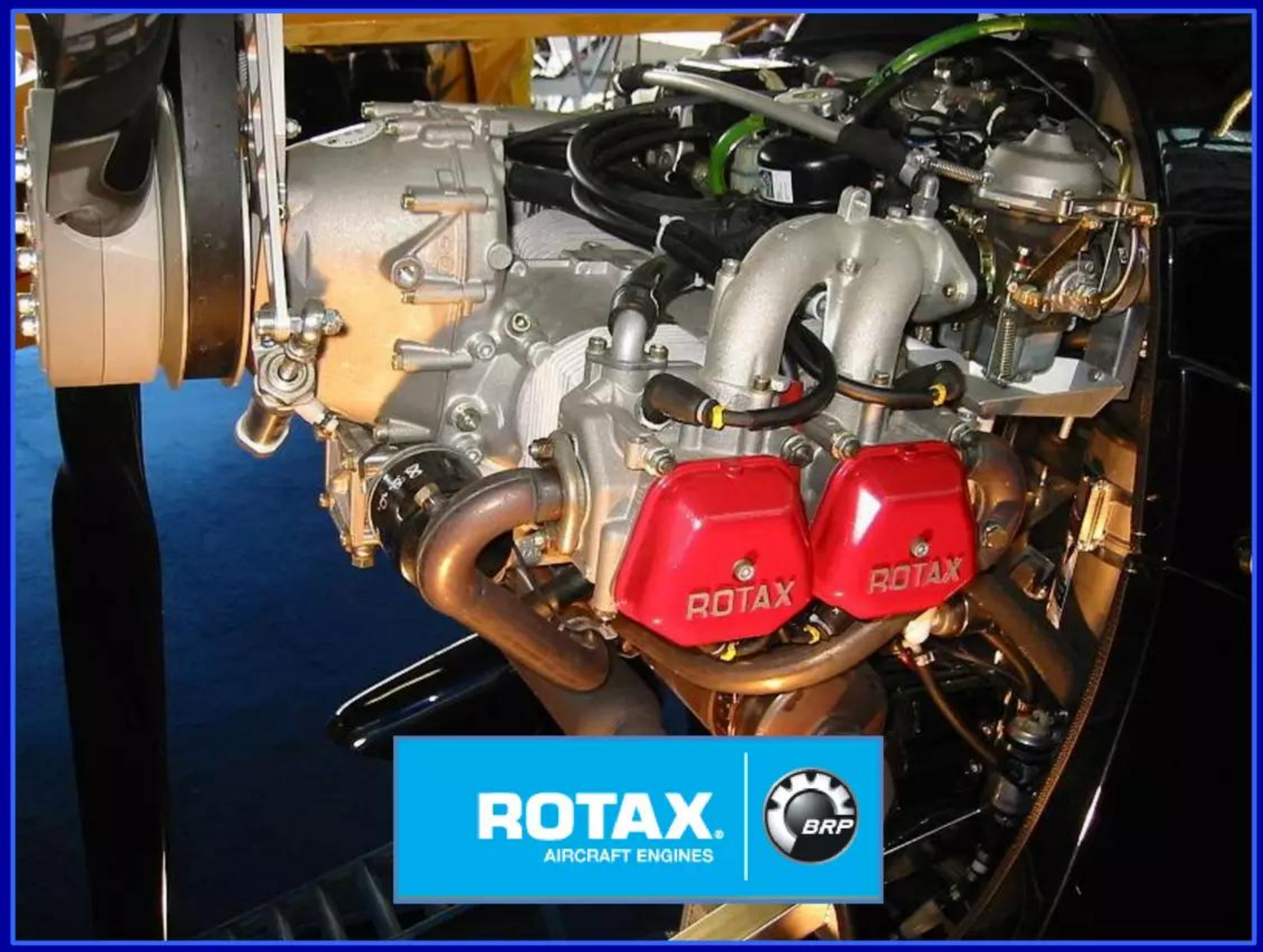
LENRs could enable all-electric drones like USA's Predator

Predator UAV is powered by Rotax 914 gasoline engine (Germany)

Engine is also used to power snowmobiles and aquatic jet skis



Source: http://www.brp-powertrain.com/desktopdefault.aspx/tabid-170/312_read-259/

Lattice Energy LLC

LENRs could enable all-electric drones like USA's Predator

Internal combustion technology allows missions of up to 24 hours

First military UAV broadly deployed and utilized in combat operations

Note: a 3-kilowatt/hour (kWh) starter/alternator supplies the UAV's electronics with electrical power; supplemented with two 14 Ah Ni-Cad auxiliary batteries.

Product	Predator MQ-1 UAV General Atomics Aeronautical Systems (USA)
Approx. price (US$)	~4.5 million
No. of passengers	Unmanned and remotely controlled - not applicable
Engine and fuel	Rotax 105 hp 4-cylinder gasoline (~77 kWh)
Fuel capacity (gallons)	Two tanks fore and aft: total ~100
Range	1,800 miles @ cruising speed of ~75 mph (max 135)
Endurance	Maximum 24 hours with full tanks of 100 octane
Operating ceiling	25,000 feet
Status	Operational and deployed in battle zones
Company website	http://www.ga-asi.com/

Lattice Energy LLC

New Super Heron UAV unveiled at 2014 Singapore air show

Israel Aerospace Industries product features new 200 hp diesel engine

Power plant is from Italian company Diesel Jet (part of Fiat group)

Unveiled at the Singapore Airshow, the Super Heron HF has been fitted wih a number of enhancements to improve the UAV's performance. The most noticable of these is the new diesel powerplant. Source: IHS/Gareth Jennings

Source: http://www.janes.com/article/33754/singapore-airshow-2014-iai-unveils-new-super-heron-hf-uav

Lattice Energy LLC

LENRs could power single-person flying vehicles

R&D prototypes under development for military and civilian applications

Source: http://www.trekaero.com/Springtail/Trek_Springtail_Specifications.jpg

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LENRs could power single-person flying vehicles

Ducted fan propulsion system can provide excellent lift capabilities

Range of LENR powered versions of such craft only limited by human endurance

Product	Springtail Exoskeleton Flying Vehicle EFV-4B (USA)
Approx. price (US$)	Unavailable
No. of passengers	1
Engine and fuel	118 hp (~ 87 kWh) rotary engine - gasoline
Fuel capacity (gallons)	12.3
Range	184 miles at cruising speed of 94 mph
Endurance	2.2^{+} hours
Operating ceiling	11,400 feet
Status	Operational R&D vehicle but not sold commercially
Company website	http://www.trekaero.com/index.html

Lattice Energy LLC

LENRs could also power nano drones like the Crazyflie

Do-it-yourself mail order kits for nano-drones are here

Crazyflie nano quadcopter by Bitcraze AB (Sweden)

"The specifications for the Crazyflie Nano Quadcopter 10-DOF are the same, but it has two added [optional] sensors: 3-axis magnetometer HMC5883L (compass); and a high precision altimeter MS5611-01BA03"

Source: http://www.bitcraze.se/crazyflie/

Source: http://www.gizmag.com/crazyflie-self-build-quadrocopter-hacking-kit/26110/pictures#7

Lattice Energy LLC

LENRs could also power nano drones like Crazyflie

One of smallest quadcopter drones on market: 9 cm and 19 grams

Open source specs have encouraged creative hacking, mods, experimentation

Product	Crazyflie nano quadcopter - Bitcraze AB (Sweden)
Approx. price (US$)	116 - 180 (depending on options)
No. of passengers	Unmanned nano UAV - not applicable
Battery type	Commercial commodity Lithium-iron phosphate 3.7 V
Battery capacity (kWh)	170 mAh (0.0006 kWh)
Range	Unclear: no one has accurately measured airspeed
Endurance	3 - 10 minutes, depending on payload weight
Status	Operational; sold to public thru online distributors
Other	Never underestimate human ingenuity
Company website	http://www.bitcraze.se/

Lattice Energy LLC

LENRs could also power small drones like InstantEye

Buffeting by winds can cause stability and course-holding problems

Physical Sciences, Inc. may have solved such issues by imitating flight of moths

Quoting the company: "InstantEye's greatest advantage is its reflexive autopilot and sensors, which allow for autonomous hovering around a GPS point while combating winds and gusts. The tiny vehicle uses the world's smallest autopilot, which was developed at PSI."

Product brochure: http://www.psicorp.com/product_service/products/InstantEye.pdf

***New Scientist* article:**

http://www.newscientist.com/article/mg22129524.300-moth-drone-stays-rock-steady-in-galeforce-winds.html

Lattice Energy LLC

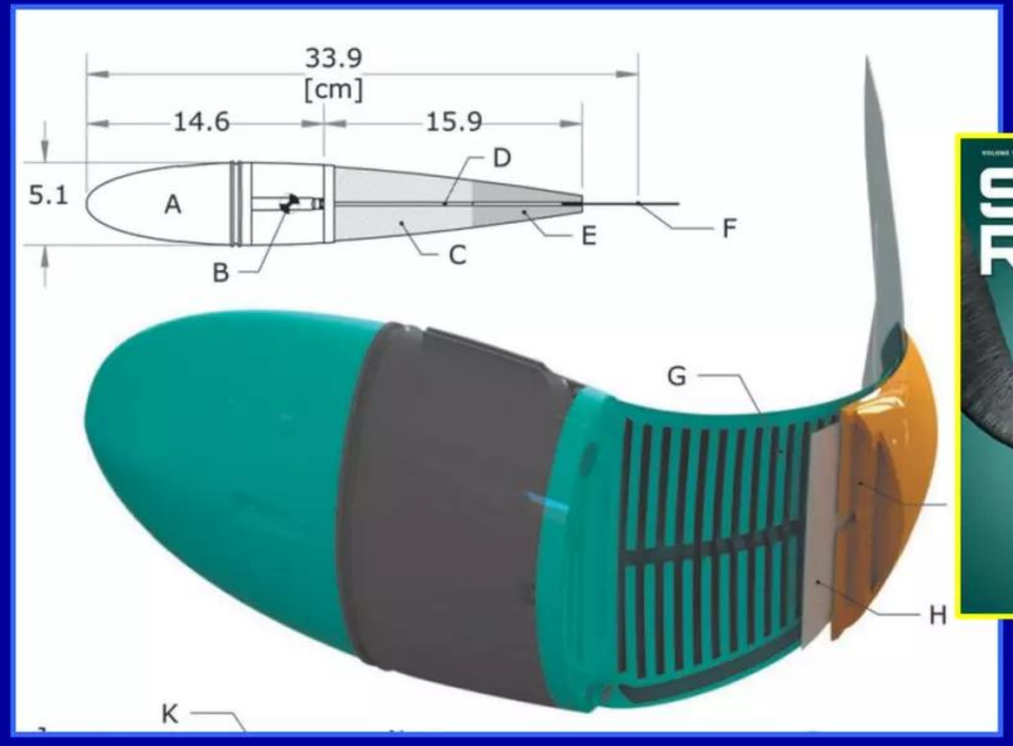
LENRs could also power soft autonomous robots

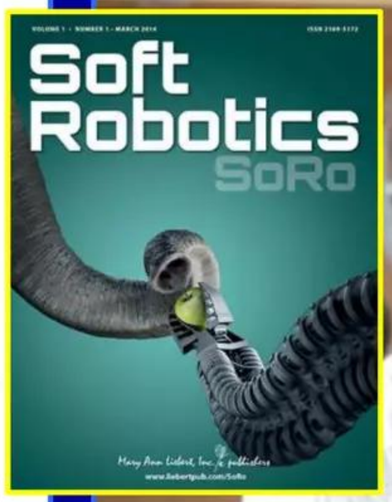
Soft-bodied robots safer - can execute more natural body movements

New refereed journal called *Soft Robotics* has just launched to cover this topic

Quoting from Marchese *et al.*'s paper: "We describe an autonomous soft-bodied robot that is both self-contained and capable of rapid, continuum-body motion. We detail the design, modeling, fabrication, and control of the soft fish, focusing on enabling the robot to perform rapid escape responses."

MIT video about piscine robo-fish : http://www.youtube.com/watch?feature=player_embedded&v=BSA_zb1ajes





***Soft Robotics* paper by Marchese *et al.* (2014): "Autonomous soft robotic fish capable of escape maneuvers …"**
http://online.liebertpub.com/doi/pdf/10.1089/soro.2013.0009

Lattice Energy LLC

LENR power sources could revolutionize airborne drones

Speed, payload, and ranges of UAVs could be dramatically increased

Enables autonomous nano vehicles with capabilities similar to birds and insects

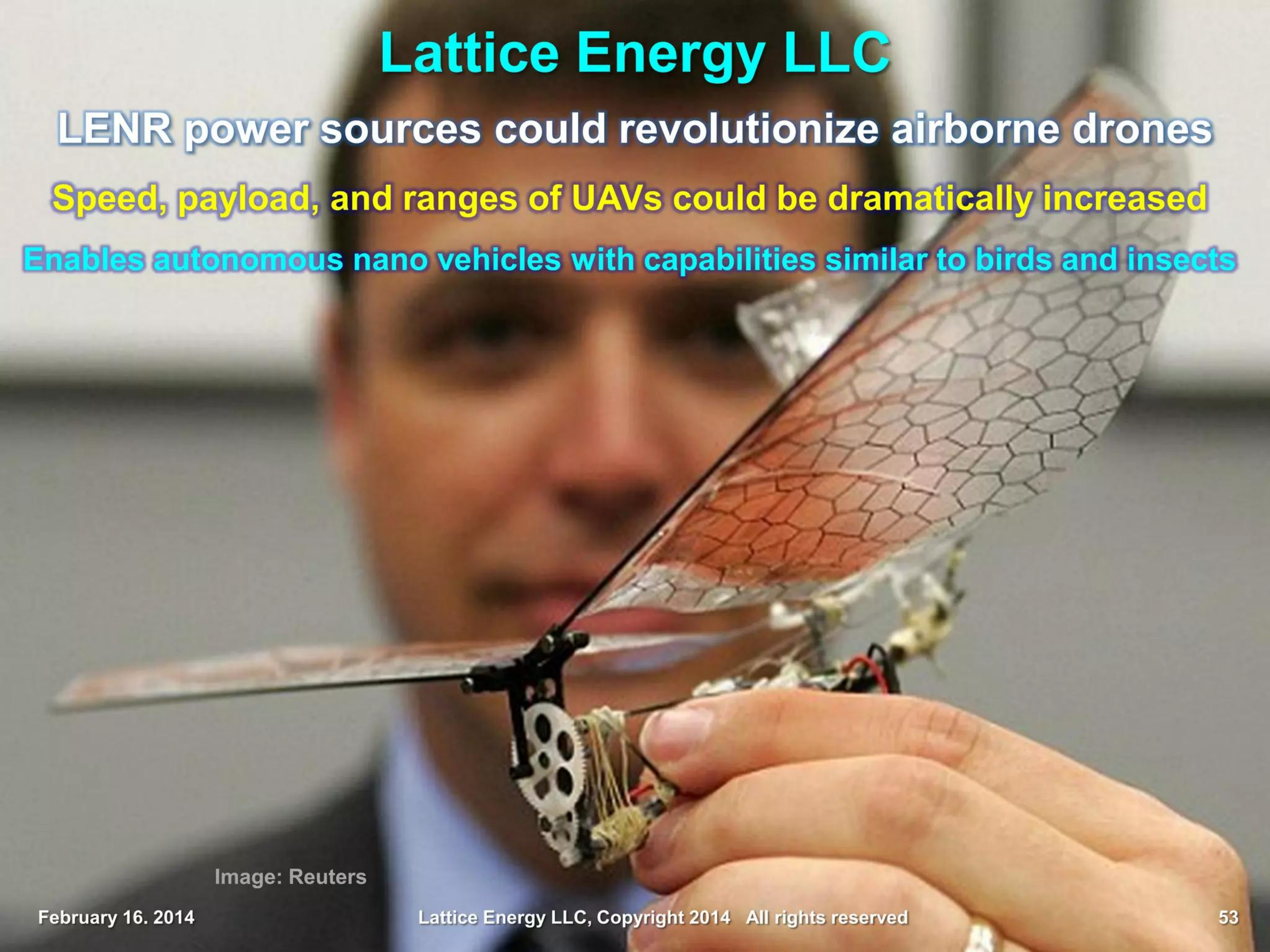


Image: Reuters

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LENRs could power all-electric cars like a Tesla

All-electric luxury family vehicles are upon us: Tesla Model S (USA)

Lattice Energy LLC

LENRs could power all-electric cars like the Tesla

Car has become iconic with cult-like throng of enthusiastic owners

Competitors from major car makers are emerging including hybrids like BMW i8

Product	Tesla Motors 4-door sedan car (USA)
Approx. price (US$)	Model S P85 edition MSRP is 106,000
No. of passengers	4 - 5
Battery type	Panasonic Lithium-ion
Battery capacity (kWh)	85 (high-end optional battery pack)
Range (miles)	Tesla claims ~300 at highway speeds without mandatory recharging
Status	Now being sold in USA and other countries
Other	Current market leader in premium all-electric cars
Company website	http://www.teslamotors.com/

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LENRs could also power single-family homes

Urban electrical grids could be improved with distributed generation

Lattice Energy LLC

LENRs could also power single-family homes in USA

Residences in industrialized countries use substantial amounts of energy

LENRs could enable widespread residential distributed generation in future

Product	Average single-family suburban residential home (USA)
Approx. price (US$)	National median existing single-family home price was recently estimated to be $196,900 (Q4 2013)
No. of occupants	Typically 2 - 5
Energy is supplied by two utility companies	Grid electricity (appliances, AC, electronics, and/or heat) and commonly natural gas (heat for furnace and/or hot water)
Electric power usage in kWh per day and year	Average U.S. household consumes 11, 698 kWh/year (2010) Equates to avg. total daily use of ~32 kWh (costs ~US$ 100/mo.)
Retail electricity cost	~US$ 0.10 kilowatt hour (average residential US - 2013)
Heating furnace cost	New 100,000 BTU 95.5% natural gas forced-air furnace US$1,400
Cost of natural gas	Average price of gas delivered to residential consumers ~US$10.00 per thousand cubic feet (EIA - 2013)
Solar PV compatible?	Yes, very synergistic; also - need batteries for LENR start-up
Grid connection issues	If home not entirely off-grid, may need synchronization of AC

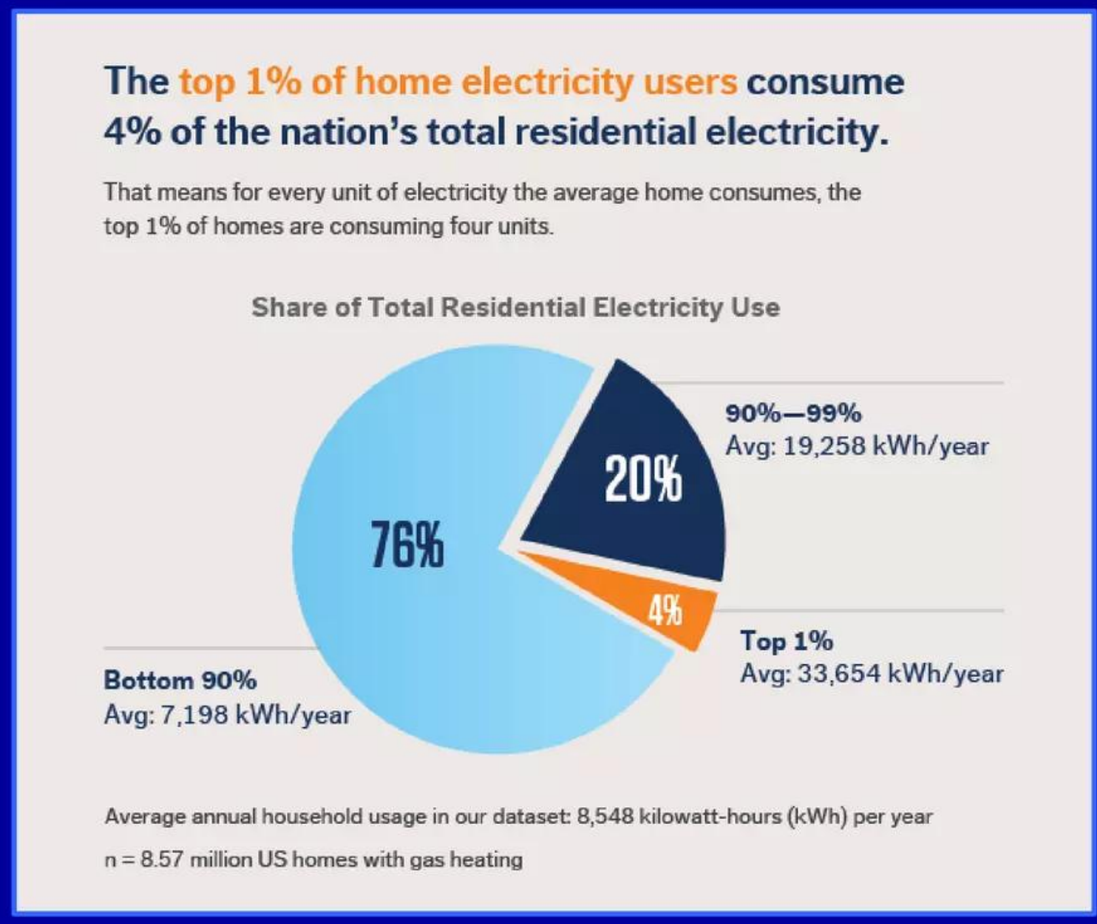
Lattice Energy LLC

LENRs could also power single-family homes in USA

Electricity usage: top 1% use ~34,000 kwh/yr vs. 7,200 for bottom 90%

LENRs could enable widespread residential distributed generation in future

- ✓ Average U.S. household consumes 11, 698 kWh/year (2010); this equates to average hourly electricity usage of ~1.3 kWh of power continuously at 120V
- ✓ Typical family home in the U.S. Upper Midwest has a heating furnace that can produce rated maximum output ~80,000 BTU/hr; equates to ~23.5 kW of heat
- ✓ If a 30 kWh LENR thermal source were integrated with a heat-to-electricity energy conversion subsystem that was only 20% efficient, the home power system would then produce ~6 kWh of electricity and 24 kW of heat which would fully satisfy household demand

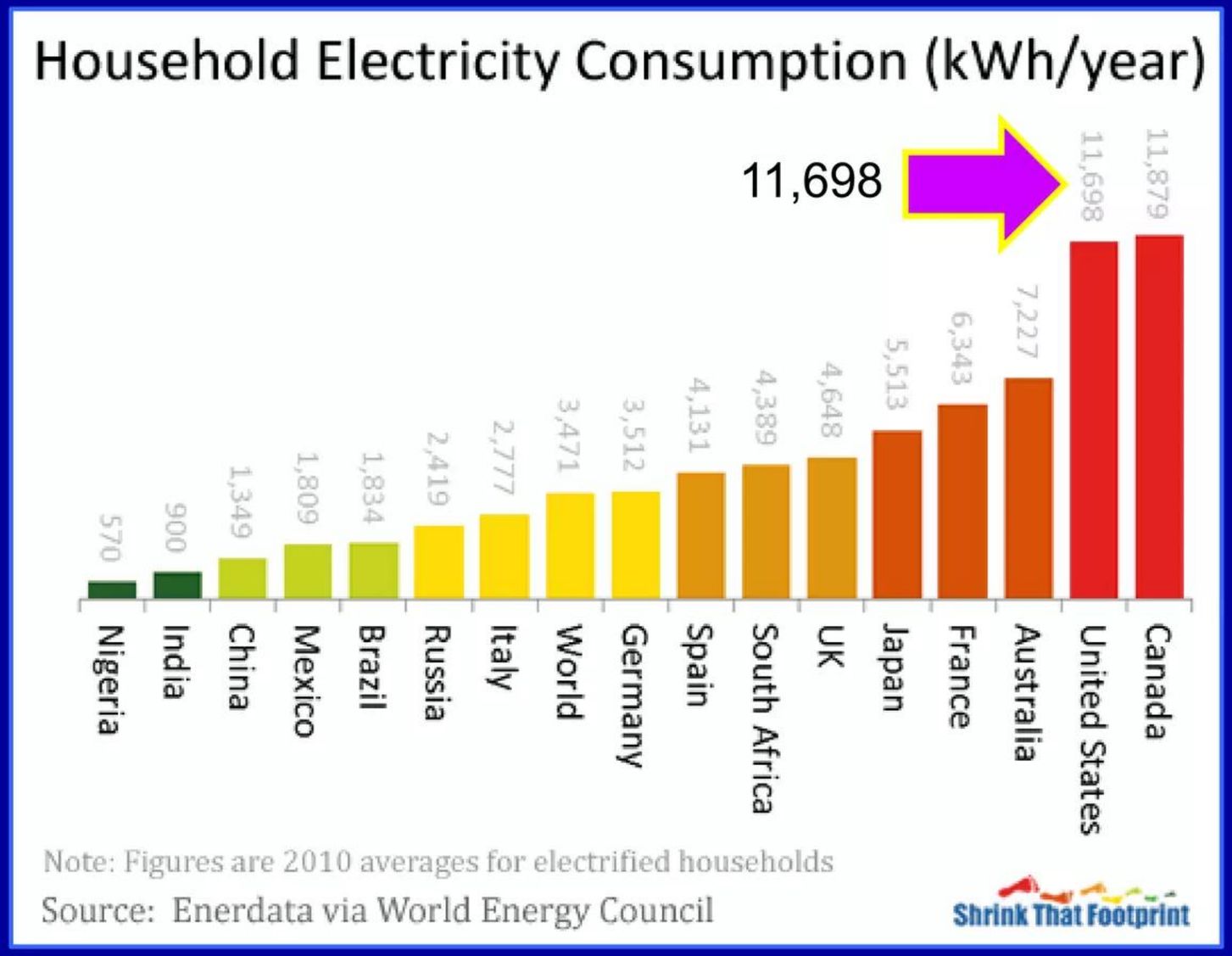


Source: http://blog.opower.com/2013/03/americas-energy-distribution-the-top-1-of-homes-consume-4-times-more-electricity-than-average-and-why-it-matters/

Lattice Energy LLC

LENRs could power residential homes around the world

Total demand ranges from ~12,000 kWh/yr down to 570 kWh/yr



Source: http://shrinkthatfootprint.com/average-household-electricity-consumption

Lattice Energy LLC

LENRs could also power single-family homes

Distributed generation strategy helps stabilize existing urban grids

Also enables cost-effective global rural electrification for people now powerless

- ✓ While steam-powered cars may have disappeared from our highways, most of the electricity for wide-area power grids worldwide is presently generated by large steam turbines
- ✓ Recently, small steam turbines have been designed and built that would be suitable for use in homes; they could be integrated with boilers heated by LENRs to supply enough heat and electricity to fully power a household located anywhere in the world; enough nanoparticulate LENR fuel for a year of operation could probably be shipped in a large FedEx box overnight or simply carried on somebody's back
- ✓ In areas with smart grids, deployment of distributed power generation with LENR-based home systems could improve robustness and stability of grid service; in rural areas with no electricity, it could finally bring power to the powerless
- ✓ Over a billion people presently have no electricity; to see size of this global problem, see: http://vimeo.com/77599467

Green Turbine™ steam generator 1.2 to 15 kWh

See: http://www.greenturbine.eu/en/product.php

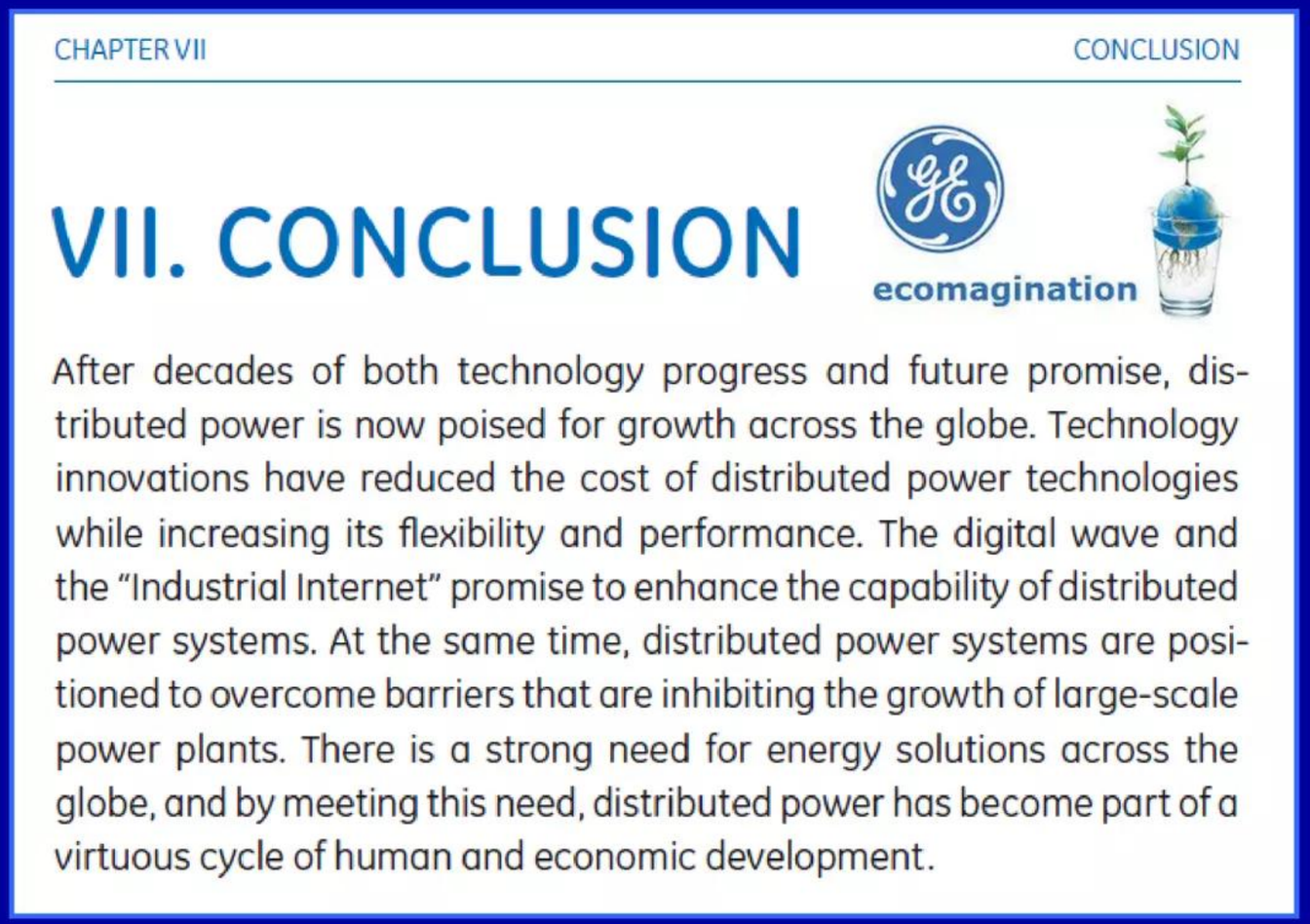
Lattice Energy LLC

LENRs could also power single-family homes

Distributed generation strategy helps stabilize existing urban grids

Also enables cost-effective global rural electrification for people now powerless

Brandon Owens of GE concluded that distributed generation is wave of the future



CHAPTER VII CONCLUSION

VII. CONCLUSION

ecomagination

After decades of both technology progress and future promise, distributed power is now poised for growth across the globe. Technology innovations have reduced the cost of distributed power technologies while increasing its flexibility and performance. The digital wave and the "Industrial Internet" promise to enhance the capability of distributed power systems. At the same time, distributed power systems are positioned to overcome barriers that are inhibiting the growth of large-scale power plants. There is a strong need for energy solutions across the globe, and by meeting this need, distributed power has become part of a virtuous cycle of human and economic development.

"The rise of distributed generation," page 39, Brandon Owens, General Electric - Ecomagination (2014)
http://www.eenews.net/assets/2014/02/25/document_gw_02.pdf

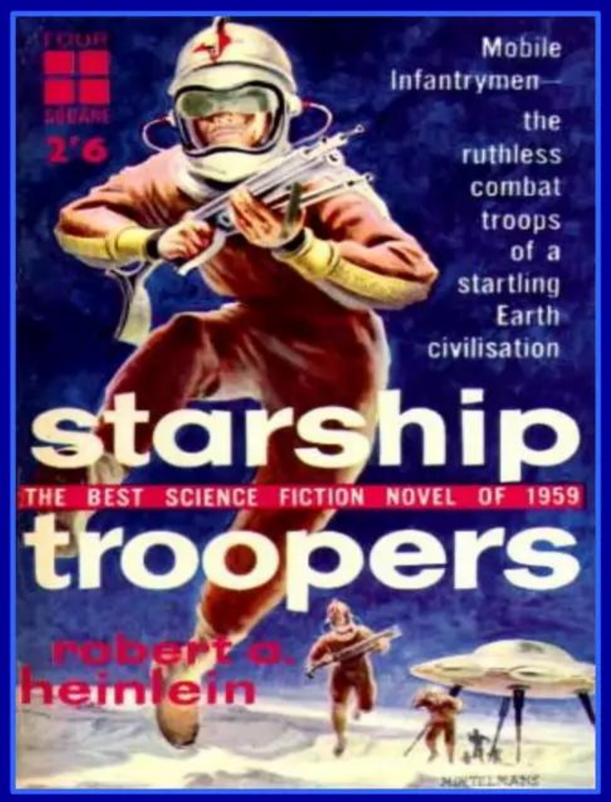
Lattice Energy LLC

LENRs could power military or civilian exoskeletons

Sometimes life imitates art: yesterday's science fiction becomes reality

Technological dream is to deploy *Starship Troopers* autonomous "power suits"

Science fiction novel 55 years ago:



"Starship Troopers" by Robert A. Heinlein
G.P. Putnam (1959) – origin of "power suits"

U.S. Army TALOS *ca.* 2013:

U.S. Army 2014 and beyond:

See: http://breakingdefense.com/2013/10/socom-wants-you-to-help-build-high-tech-iron-man-armor/

Lattice Energy LLC

LENRs could power military or civilian exoskeletons

February 25, 2014: President Obama announces U.S. Army's *Iron Man*

Very early versions of *Starship Troopers* autonomous "power suits"

See CNN video clip on YouTube (49 seconds running time): http://www.youtube.com/watch?v=77pnVFLkUjM/

Also see: "Obama says US Army is building a real Iron Man and no, he is not joking "
Jesus Diaz, SPLOID (gizmodo.com) February 27, 2014
http://sploid.gizmodo.com/obama-says-us-army-is-building-real-iron-man-and-no-he-1532582334

Lattice Energy LLC

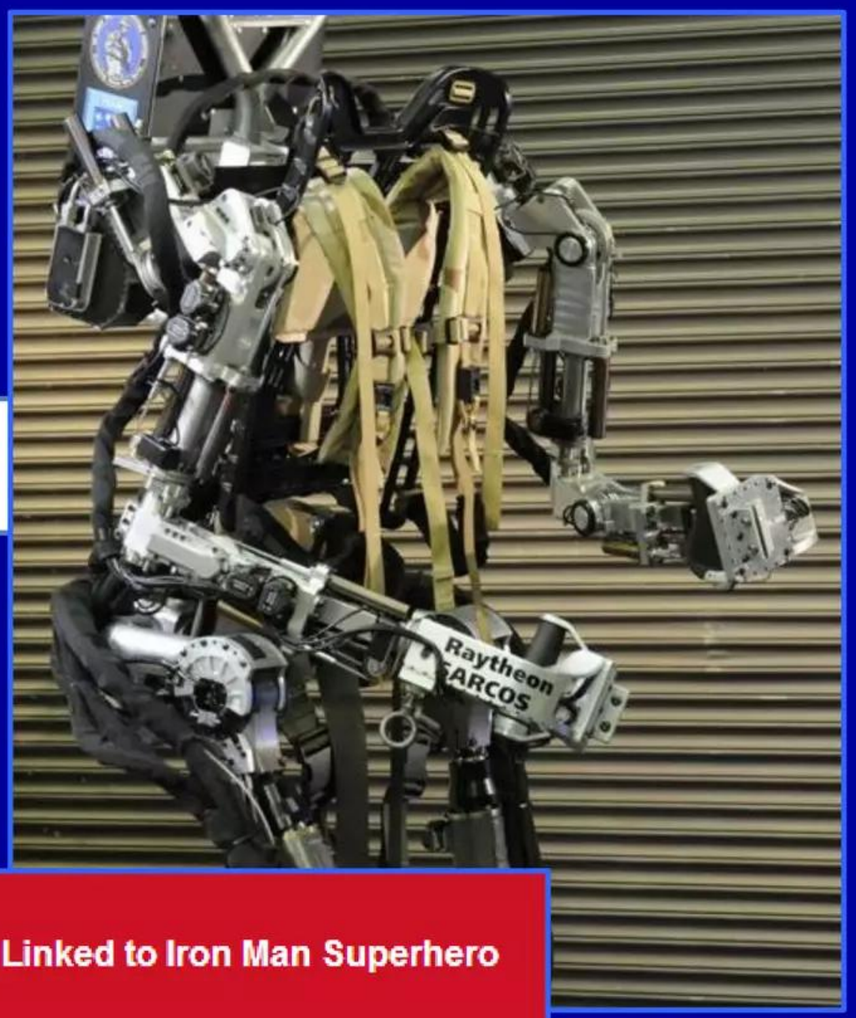
LENRs could power military or civilian exoskeletons

Raytheon/SARCOS XOS 2 *ca.* 2013 being developed for US military

Prototypes of full exoskeletons are presently tethered to external power sources

See power cable tether

Raytheon



Raytheon Sarcos Exoskeleton Robotic Suit Linked to Iron Man Superhero

See: http://www.army-technology.com/projects/raytheon-xos-2-exoskeleton-us/

Lattice Energy LLC

LENRs could power military or civilian exoskeletons

With enough onboard power exoskeletons morph into humanoid robots

Today's batteries have insufficient energy density to fulfill all of military's dreams

- ✓ Full exoskeletons suitable for military ground combat operations require onboard portable power sources that can provide a soldier's "power suit" with kilowatts of electricity roughly continuously for duration of a mission
- ✓ Electric power requirements of full exoskeletons can thus range from ~1 - 3 kWh for low-end, bare bones systems up to 5 - 10 kWh for high-end systems capable of carrying heavy loads and moving very rapidly over rough terrain. Minimum mission duration of interest for US Army SOCOM applications is 72 hours, so one needs to have a portable power source that can deliver 72 - 720 kWh over that time period without mandatory resupply
- ✓ Tesla Model S Lithium-ion battery pack stores ~85 kWh but unfortunately weighs ~1,300 pounds, so batteries are ruled-out --- LENRs can potentially generate such power

Iconic "Terminator" robot

"The Terminator" was cult-classic 1984 American science fiction action film starring Arnold Schwarzenegger

Lattice Energy LLC

LENRs could power humanoid and other types of robots

Power source energy density is key enabler for autonomous robotics

Large robots like six foot tall Atlas presently tethered to external power sources

- ✓ Today, large autonomous robotic systems must either be tethered to an external power source or use batteries that cannot store enough energy for commercially or militarily significant mission durations. Battery energy densities are inadequate
- ✓ Robotics is going mainstream commercial: Google acquired Boston Dynamics in December 2013 for an undisclosed sum; business logic behind purchase was not disclosed publicly by Google management
- ✓ LENR-based portable power sources would be a paradigm shifting game changer for autonomous robotic systems such as the humanoid "Atlas", quasi-canine "BigDog", and varied piscine robo-fish
- ✓ LENRs could someday enable, "Look ma, no tether!"

Google

Boston Dynamics "Atlas" robot

Image credit: Boston Dynamics

Lattice Energy LLC

LENRs could power high performance undersea UAVs

LENR energy density enables superior heat source for steam technology

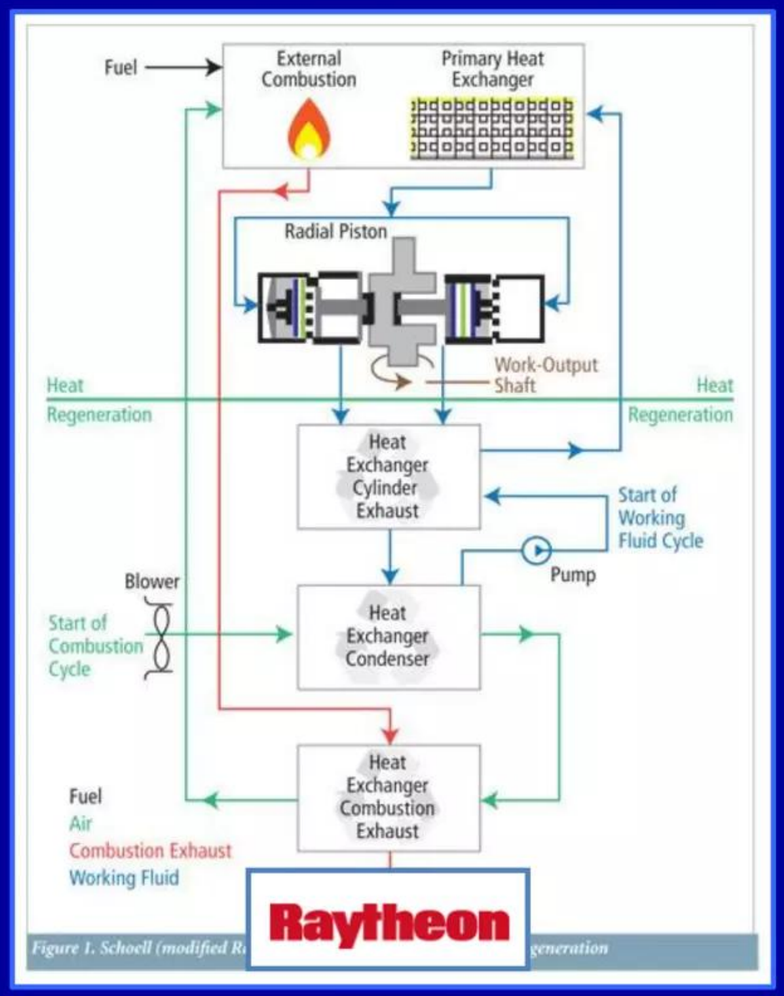
Integration could enable a renaissance of 21st century mobile steam propulsion

Quoting from Raytheon's website:

"The U.S. Navy has called for increased stamina in unmanned undersea vehicles to enable missions that can last for weeks, not just one or two days; this exceeds the energy capability of traditional battery technologies. Raytheon engineers are addressing the need for an alternative power source through the use of external combustion engines and monopropellant fuels. The team investigated a number of engine types. Particularly promising technologies included a modified Rankine cycle engine developed by Cyclone Power Technologies, Inc. ... The U.S. Navy employs a number of large-diameter, large-payload undersea vehicles, and has plans to expand that fleet in the next decade. The Navy requires that these next-generation undersea vehicles have high speed and long endurance (as long as 120 days). Game-changing technologies like this are needed to address these undersea vehicle requirements."

LENR-based heat sources could be integrated with modern steam engines or turbines to provide higher levels of performance and longer mission duration

Raytheon: steam engines for undersea power and propulsion (U.S. Navy)



Source: http://www.raytheon.com/newsroom/technology_today/2011_i1/engine.html

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

By 1920 steam-powered vehicles had essentially disappeared in U.S.A.

LENR heat sources could unleash revolutionary change in vehicular applications

- ✓ In 1900, U.S. auto industry produced 4,192 vehicles comprising 1,681 powered by steam; 1,575 by electric batteries; and only 938 by gasoline powered internal combustion engines (ICEs). By 1920 ICEs had triumphed; electric and steam cars subsequently disappeared from roads after ICE technology lock-in occurred worldwide
- ✓ Besides development of turn-key electric starters for ICE vehicles and absence of warm-up delays for gasoline ICEs, power-to-weight ratios for steam systems (where power system weight = powertrain + fuel tank + onboard fuel) were significantly lower than those for ICE vehicles
- ✓ LENR steam systems could potentially erase this long-held completive advantage of ICEs because, although modern steam turbines by themselves may be marginally heavier than comparable gasoline or diesel powered ICE engines, LENR fuel's weight would be minuscule vs. that of gasoline because LENR energy density is 5,000x larger

Modified Rankine cycle steam engine by Cyclone Power Technologies

Source:
http://www.cyclonepower.com/works.html

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

Many of them are based on Rankine cycle using superheated steam

While efficiencies lower than large systems can be good for CHP applications

Small system developed by Green Turbine is ideal for integration with LENR-fired boilers

Credit: Green Turbine

Technical Description	Green Turbine 15 kW
Dimensions:	length: 37 cm, width: 26 cm (14.6 x 10 in)
Weight:	25 kg (882 oz)
Inlet conditions:	Superheated Steam 10 - 12 bar abs. Temp. 200-220°C (392-428°F)
Outlet conditions	0,1 bar abs. 40° C (104 °F)
Steam consumption for 15 kW	0,04 kg/sec
Basic steam rate:	9,8 kg/kWh (steam to electricity after rectification)
Power output:	3 phase AC 1000 Hz, after rectification: DC. Voltage depends upon type of generator. Default is 500 V
Design speed:	26.000 rpm
Speed of steam after nozzle:	> 1000 m/sec
Temperature of turbine housing:	45°C (113 °F)

Credit: Green Turbine

See: http://www.greenturbine.eu/en/home.php

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

Efforts underway to develop micro steam devices for Watt-scale power

"Preliminary design of a MEMS steam turbine power plant-on-a-chip"

Fréchette *et al.* (2003) --- tiny but now vastly less efficient than large systems

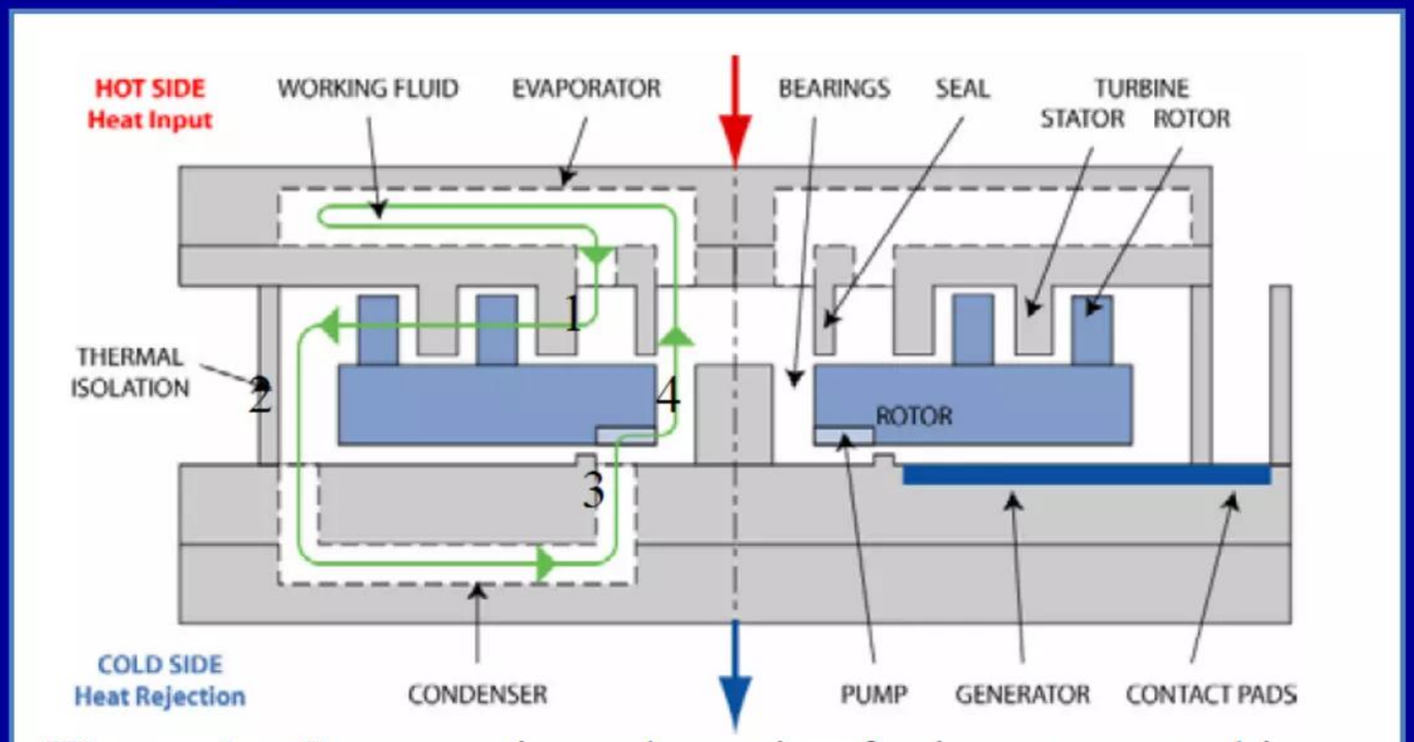


Figure 1 - Cross-section schematic of micro steam-turbine power plant-on-a-chip. Constructed from 5 silicon wafers that are deep reactive ion etched and bonded to integrate the components on a single chip.

Source for copy of paper: http://www.eureka.gme.usherb.ca/memslab/docs/PowerMEMS-Rankine-paper.pdf

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

Utilize new thermal-to-electric systems developed for CSP applications

Engineer efficient thermal interface between LENR heat source and CSP receiver

- ✓ Earlier in presentation we discussed how commercial versions of LENR thermal sources could likely produce neutron fluxes of 1 x 10^{14} cm^2/sec that can create thermal power fluxes of ~ 428 W/cm^2 using a Lithium target fuel
- ✓ Thermal fluxes created at focus receivers of concentrated solar power (CSP) systems can reach values on the order of roughly 200 - 400 W/cm^2 ; ~ matches LENR fluxes above
- ✓ Google, Abengoa Solar, Brayton Energy, and others have investigated and/or developed Brayton cycle thermal-to-electric conversion systems for use in CSP applications
- ✓ Minimizing technology development risks, similarity in sizes of thermal fluxes creates potential opportunities to adapt and integrate such Brayton cycle CSP systems for use in modular LENR-based power generation systems

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

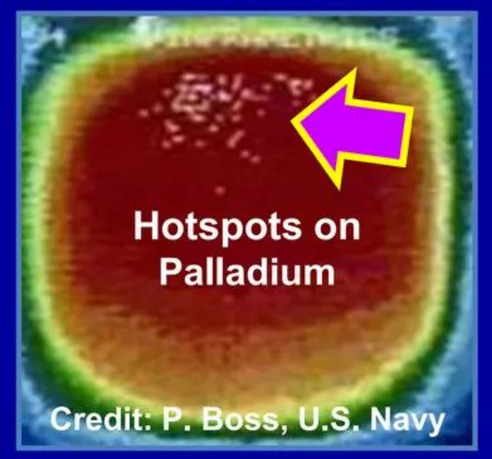
Utilize new thermal-to-electric systems developed for CSP applications

LENRs generate extremely high temperatures ideally suited for the Brayton cycle

- ✓ LENRs intrinsically occur in localized micron-scale LENR-active sites on ~planar surfaces or curved surfaces of nanoparticles
- ✓ Tiny LENR-active sites only 'live' for 200 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 3,700 - 5,700° C; LENR-active sites will spontaneously reform under right conditions in properly engineered devices
- ✓ Microscopic 100-micron LENR hotspot can release 5⁺ Watts of heat in less than 400 nanoseconds; create crater-like features on surfaces that are visible in SEM images and showing clear evidence for flash-boiling of precious and refractory metals
- ✓ Peak local LENR power density can hit > 1.0 x 10^{21} Joules/sec·m^3
- ✓ Control temps in LENR systems by regulating input energy and/or total area/volumetric densities of LENR-active sites

100 μ crater in Palladium

IR video of LENR hotspots



http://www.youtube.com/watch?v=OUVmOQXBS68

Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

Utilize new thermal-to-electric systems developed for CSP applications

Brayton cycle LENR-based CHP power generation systems might be 30% efficient

High LENR temps may enable development of 50 - 60% efficient combined cycle systems

- ✓ Google investigated development of Brayton cycle for CSP system because Brayton does not require any water to produce power or for cooling (air in, air out) and design could scale up to 1 Megawatt; they estimated Brayton engine efficiency by itself at 37% and integrated system efficiency at ~30%; abandoned project for many reasons
- ✓ As we have shown, LENRs get extremely hot; limitations on macroscopic working temperatures in LENR systems would mostly be determined by thermal tolerances of materials used in system. If its components can reliably withstand extremely high temperatures over long periods of time, LENRs could provide whatever temperatures are necessary, well-tailored to specific application requirements. This opens-up a possibility to maybe develop combined cycle LENR-based power systems that scale from a few kilowatts up to megawatts; then might achieve 50 - 60% overall efficiencies
- ✓ Since no combustion, external venting of exhaust gases is unnecessary; thus LENR-based Brayton-cycle-only power systems could safely be used indoors for combined heat and power (CHP); effective application efficiencies could then approach 80 - 90%

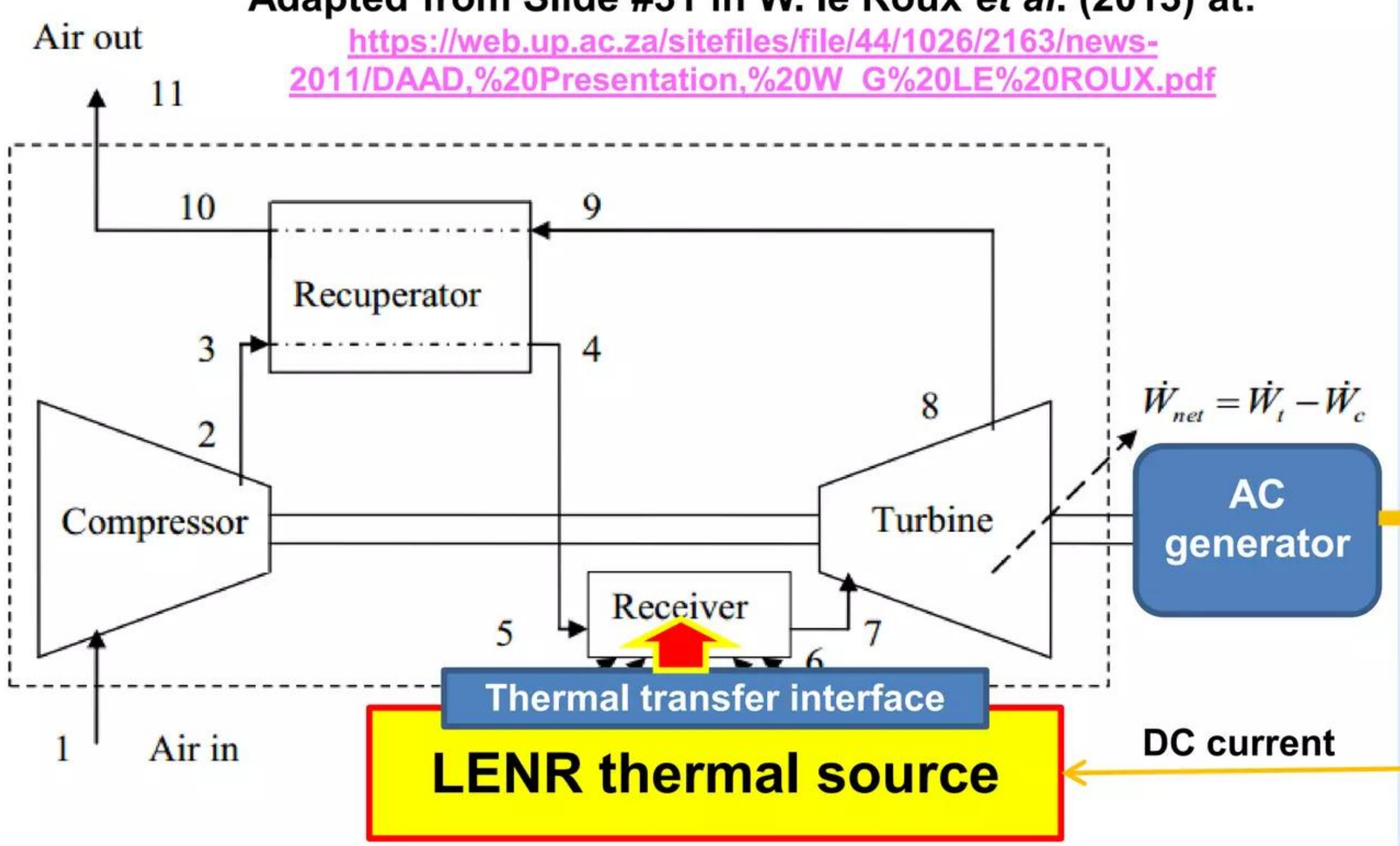
Lattice Energy LLC

LENRs could power Rankine and Brayton cycle engines

Utilize new thermal-to-electric systems developed for CSP applications

Schematic system block diagram: LENR-based Brayton cycle AC power generator

Adapted from Slide #31 in W. le Roux *et al.* (2013) at:
https://web.up.ac.za/sitefiles/file/44/1026/2163/news-2011/DAAD,%20Presentation,%20W_G%20LE%20ROUX.pdf



Lithium LENR target fuel has a maximum theoretical electrical input vs. thermal output energy gain-ratio of ~34x; at least a ~10x to 15x gain should be achievable in practice. Breakeven gain ratio is ~3x with 33% thermal-to-electric conversion efficiency; is then self-sustaining until fuel gone

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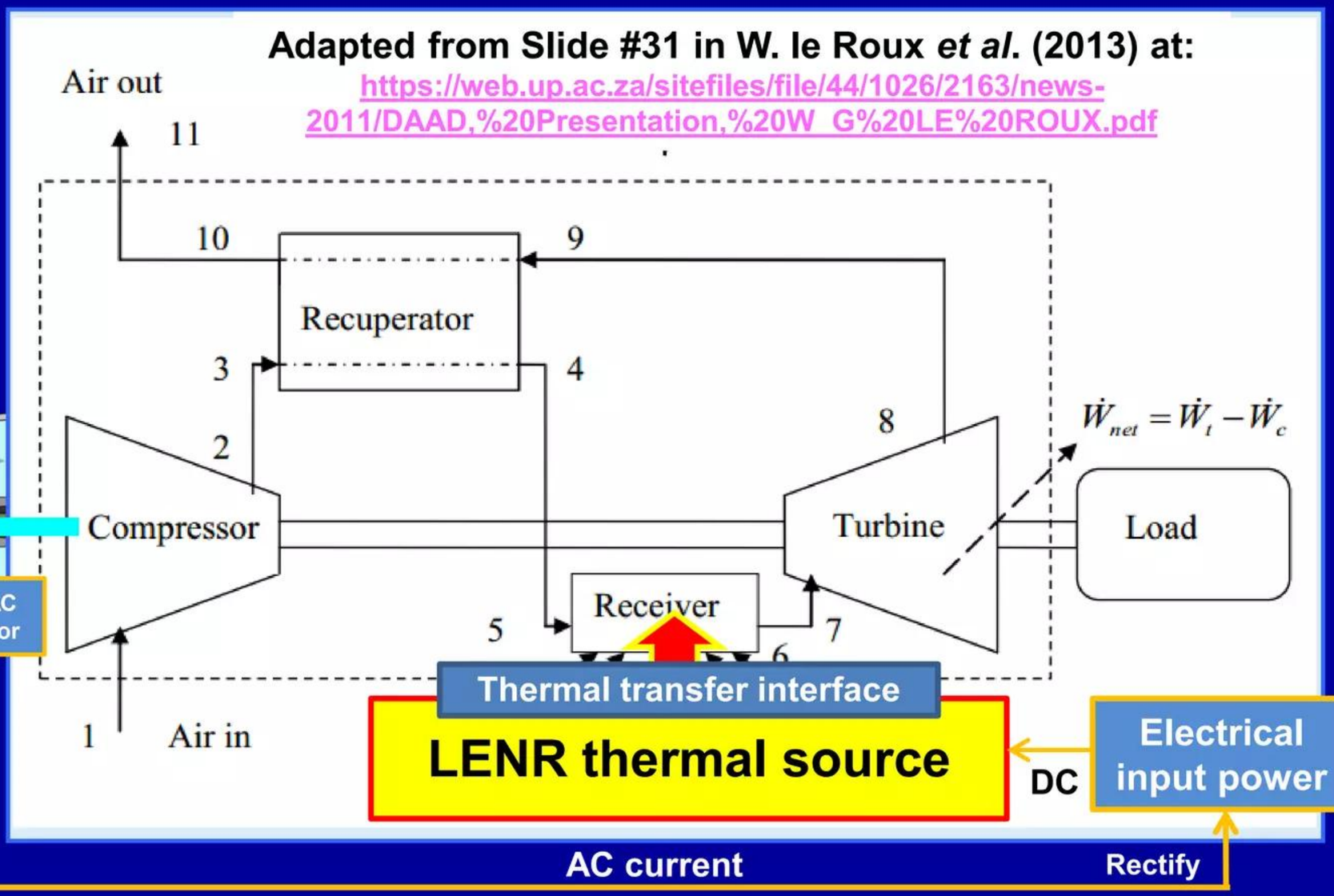
LENRs could power Rankine and Brayton cycle engines

LENR-based Brayton cycle system can be used for direct propulsion

Turboprop: gearbox is used to drive a rotating propeller for aircraft propulsion

Most jet aircraft engines use the Brayton cycle

Adapted from Slide #31 in W. le Roux *et al.* (2013) at:
https://web.up.ac.za/sitefiles/file/44/1026/2163/news-2011/DAAD,%20Presentation,%20W_G%20LE%20ROUX.pdf



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Enormous increases in product performance with LENRs

Intrinsic energy density of LENRs is 5,000x > than chemical process

Commercial LENR systems could probably achieve 10x to 100x chemical

Illustrative range of product capabilities if LENR technology were commercialized:

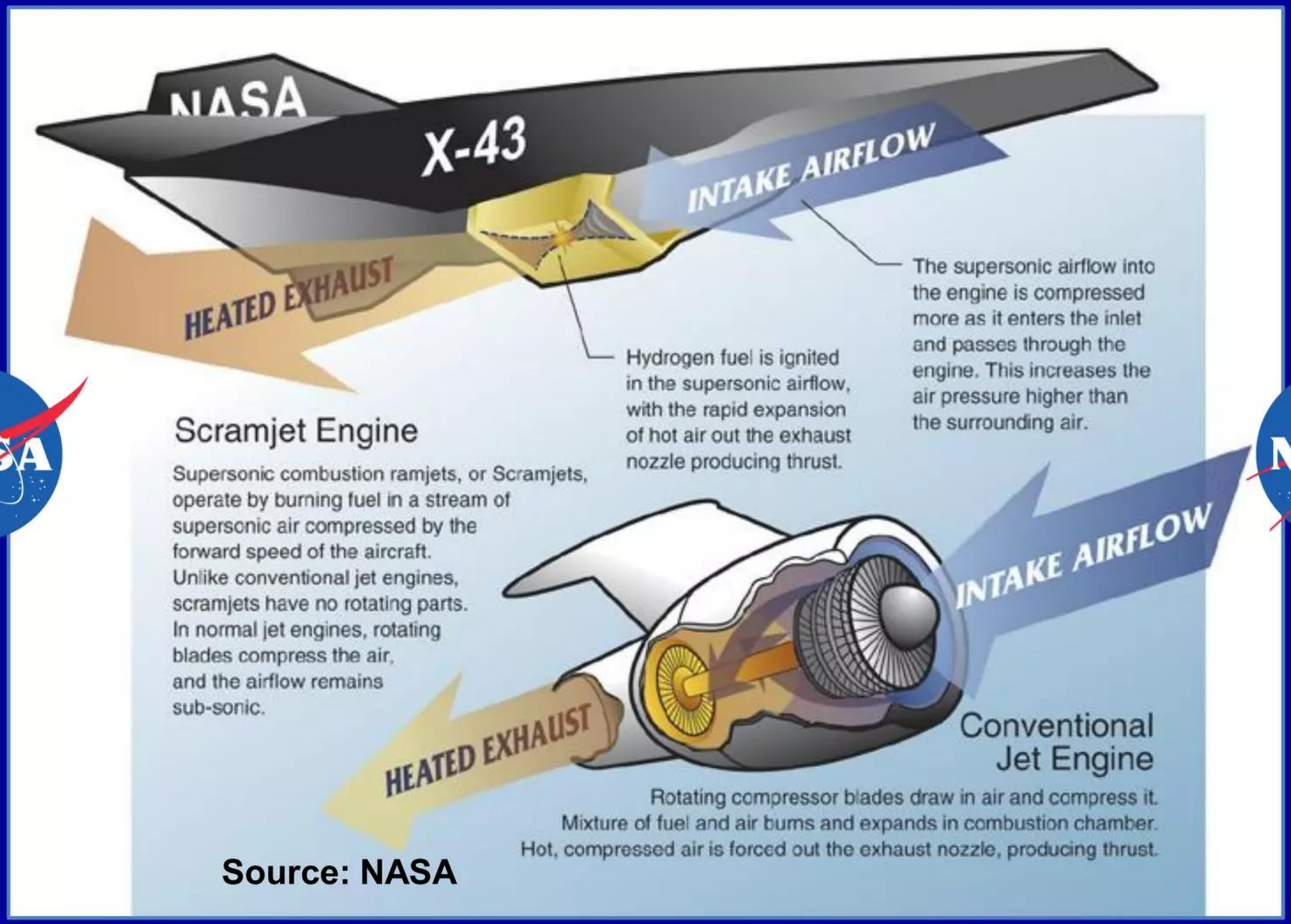
Product Name	Present capabilities with today's power sources Range (endurance)	Vastly enhanced capabilities with future LENR-based power sources	
		10x chemical	100x chemical
Yuneec e-430	150 miles (2.5 hours)	1,500 (25)	15,000 (250)
Airbus E-Fan 2.0	99 miles (1 hour)	990 (10)	9,900 (100)
Predator MQ-1	1,800 miles (24 hours)	18,000 (240)	180,000 (2,400)
Super Heron	est. ~4,000 miles (45^+ hours?)	40,000 (450^+)	400,000 (4,500)
Springtail	184 miles @ 94 mph (2.2^+ hours)	1,840 (200^+)	18,400 ($2,000^+$)
Crazyflie	Speed not measured (3 - 10 minutes)	? (30 - 100 min.)	? (maybe 5 - 17 hrs.)
InstantEye	est. ~8 miles @ 25 mph (18 - 20 min.)	est. 80 (3.2 hrs.)	800 (32 hrs.)
Tesla Model S	~300 miles (4 - 5 hours @ 70 mph)	3,000 (40 - 50)	30,000 (400 - 500)
Exoskeletons and autonomous robots	Require tether cables connected to external power sources	Duration of autonomous activity could be extended to weeks or even months	

Note: roughly 730 hours in month and 8,760 hours in a year; average U.S. car engine runs for ~5,000 hrs over lifetime

Lattice Energy LLC

LENR-heated dusty plasma scramjets for hypersonic aircraft

Fast reaction rates of LENRs and E-M triggering ideal for such engines



Source: NASA

Lattice Energy LLC

Lockheed Martin SR-72 would be unmanned aircraft

Earlier manned SR-71 Blackbird cruised at an airspeed of ~ Mach 3.0

SR-72's present concept integrates a low-speed turbine engine with a scramjet

LOCKHEED MARTIN

"Envisioned as an unmanned aircraft, the SR-72 would fly at speeds up to Mach 6, or six times the speed of sound."

"SR-72's design incorporates lessons learned from the HTV-2, which flew to a top speed of Mach 20, or 13,000 mph, with a surface temperature of 3500°F."

Source: Lockheed Martin website
http://www.lockheedmartin.com/us/news/features/2013/sr-72.html

Source: Lockheed Martin

Lattice Energy LLC

Lockheed Martin SR-72 would be unmanned aircraft

Present “combined cycle” concept integrates turbine and a scramjet

Source: Lockheed Martin

Lattice Energy LLC

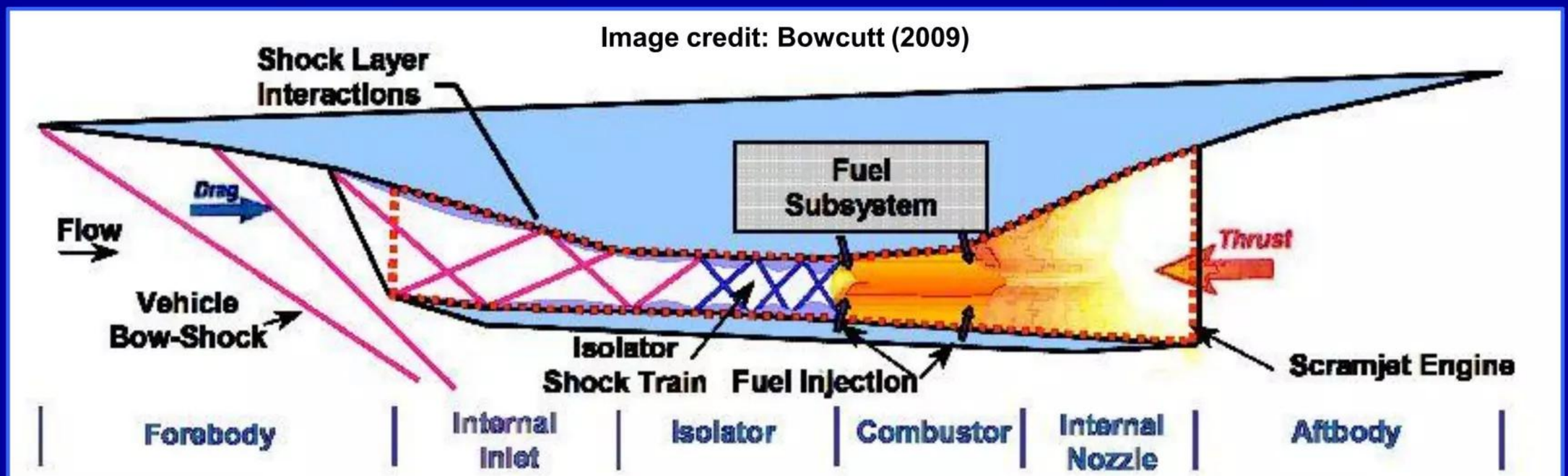
Airflow through scramjet engine is at supersonic speeds

Concept of engine operation is explained in graphic by Bowcutt (2009)

Key goal: release as much energy as is possible prior to exhaust exiting engine

FIG. 3 - Air-breathing supersonic combustion ramjet (scramjet)

Image credit: Bowcutt (2009)



"Plasma-Assisted Ignition and Combustion
A. Starikovskiy and N. Aleksandrov
Chapter 12 in "Aeronautics and Astronautics," M. Mulder, *ed.*, ISBN 978-953-307-473-3 (2011)

Source: http://www.intechopen.com/books/aeronautics-and-astronautics/plasma-assisted-ignition-and-combustion

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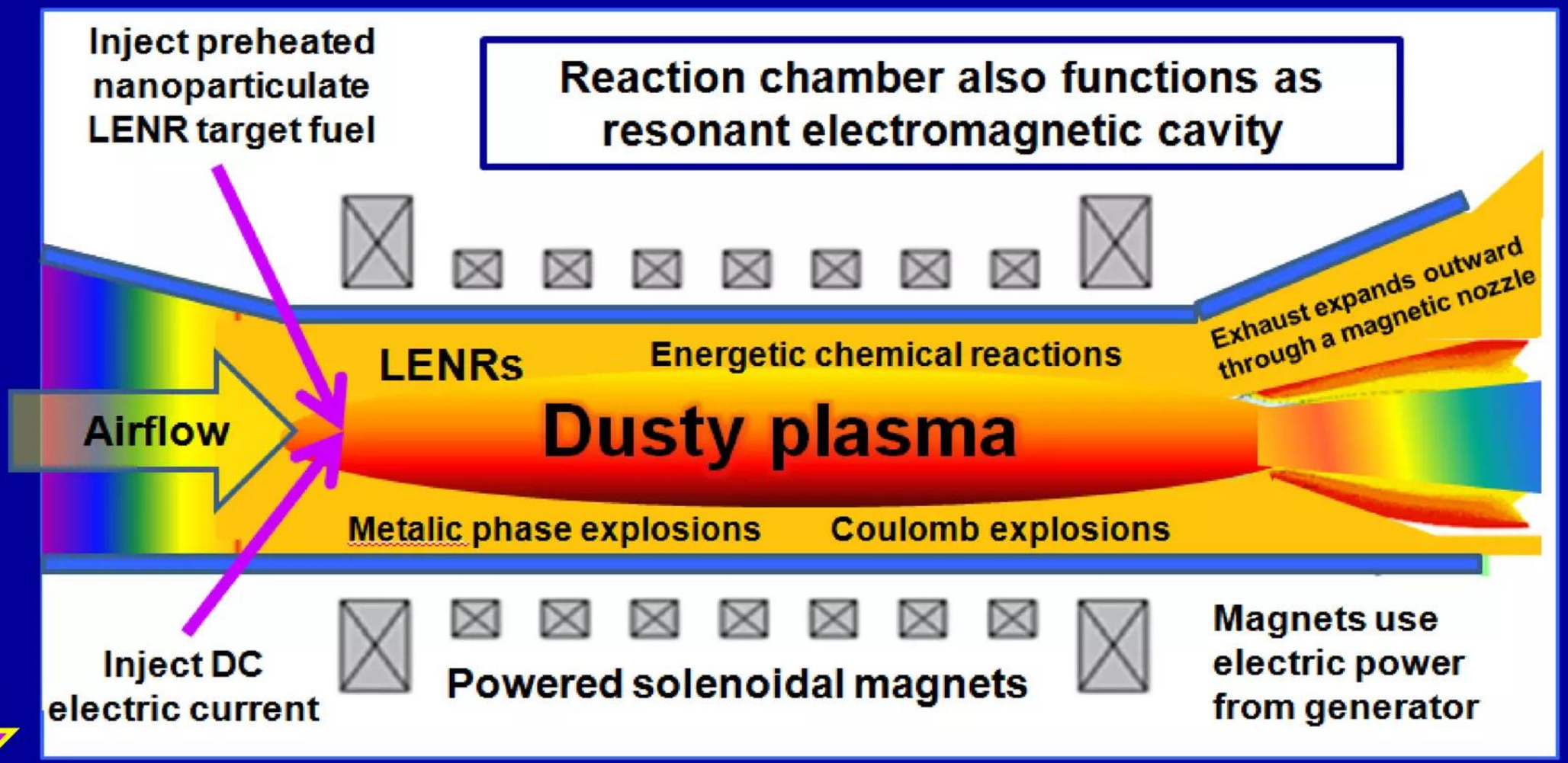
Lattice's concept for LENR dusty plasma scramjet engine

Plasma kept away from walls and confined with an axial magnetic field

LENRs triggered with E-M fields so tiny propagation delays in reaction chamber

Thrust is produced by LENRs, metallic phase/Coulomb explosions, and chemical reactions



For details see: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-radiationfree-nuclear-propulsion-for-advanced-hypersonic-aircraft-june-13-2014

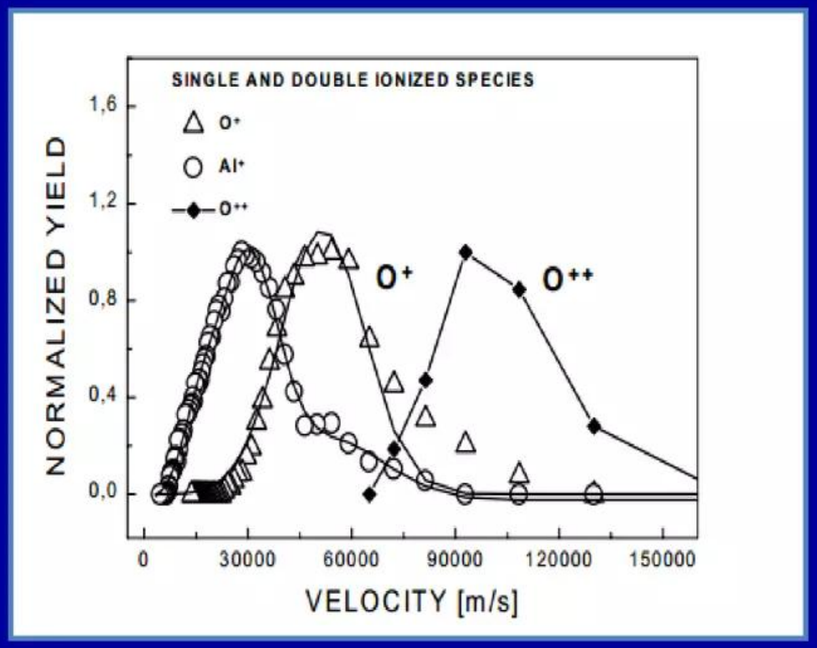
Lattice Energy LLC

LENR scramjet's average exhaust velocity presently unclear

Exhaust contains many materials traveling at very different velocities

e.g. O^+ O^{++} ions likely moving at speeds of 30,000 to 150,000 meters/second

- ✓ Enormous flexibility in designing and engineering LENR nanoparticle target fuels - huge selection of many different elements and materials (fuel-wise, ULM neutrons quite omnivorous as to captures)
- ✓ Design LENR fuel nanoparticles so LENR-sites triggered thereon will release just exactly enough energy to totally vaporize the entire nanoparticle
- ✓ Some charged particles in exhaust stream would be moving at extremely high average velocities
- ✓ Combination of metallic phase explosions and Coulomb explosions will cause extreme volume expansions and heating; suggests good thrust
- ✓ Need experimentation to determine likely average exhaust velocity and thrust of an LENR-powered scramjet engine for specific types of target fuels



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LENR dusty plasma scramjet could be revolutionary

Simultaneously use nuclear and chemical reactions to produce thrust

- ✓ Unlike SR-72, Lattice would integrate LENR dusty plasma scramjet engine with an LENR-powered 50^{+}% efficient Brayton combined cycle turbine to generate DC electricity for aircraft systems; direct waste heat from turbine into scramjet or air bypass flow if feasible
- ✓ Some DC power from turbine generator injected into dusty plasma to trigger LENRs on fuel
- ✓ LENR scramjet reaction chamber walls irradiated with IR/UV radiation will get extremely hot and probably need cooling even with containment of plasma by axial magnetic field. If hypersonic aerodynamics permit, should investigate possibility of creating an air bypass flow surrounding scramjet engine walls to cool them. If this were proven feasible, might have an opportunity to create the scramjet analogue of a high-bypass turbofan engine
- ✓ Incredibly high energy densities and minimal mass of LENR nanoparticulate target fuels might allow an LENR dusty plasma scramjet the luxury of carrying multiple fuel types that are optimized for different flight envelopes. A target fuel containing much Oxygen could be used to operate like a rocket for take-off and then switched to a hypersonic fuel type when proper airspeed is reached --- could utilize optimized combinations of nuclear and very energetic chemical reactions simultaneously inside very same engine reaction chamber
- ✓ While radioactivity and radiation are not issues, given complexity of 'witches brews' inside LENR scramjet reaction chambers, must evaluate environmental impact of exhaust streams
- ✓ Thrust control achieved by regulating input of DC current and target fuel injection rates

Lattice Energy LLC

LENRs could potentially revolutionize world as we know it

- ✓ Successful commercialization and integration of LENR-based power sources would create dramatic increases in performance capabilities of a vast array of products that span consumer electronics, homes, motor vehicles, robots, and small aircraft; outputs of up to a few hundred kWh are all that is needed to catalyze this revolution
- ✓ Elsewhere Lattice has explained how it may be technologically possible to process aromatic fractions found naturally in petroleum and coal to transform them into LENR fuels where Carbon is transmuted with safe low energy neutrons to release thermal energy rather than combusting Carbon with Oxygen as is the case today in most of mankind's power generation activities. This would release 5 million times more thermal energy than oxidative chemical processes and without production of CO_2. Real $ price of energy could drop dramatically as energy supplies skyrocket
- ✓ With the advent of broad global deployment LENR power generation technologies, the world's economies would not be flirting with 'running on empty' for energy in the foreseeable future, as might be the case if we continue profligate combustion of carbonaceous fossil fuels. Our beleaguered Mother Earth might also get a semi-permanent reprieve from further acceleration of present global warming trends and other types of deleterious climate change that could affect yields of food crops
- ✓ Last but not least, this would democratize universal access to affordable clean, green energy for billions of people who presently live with little or no electricity

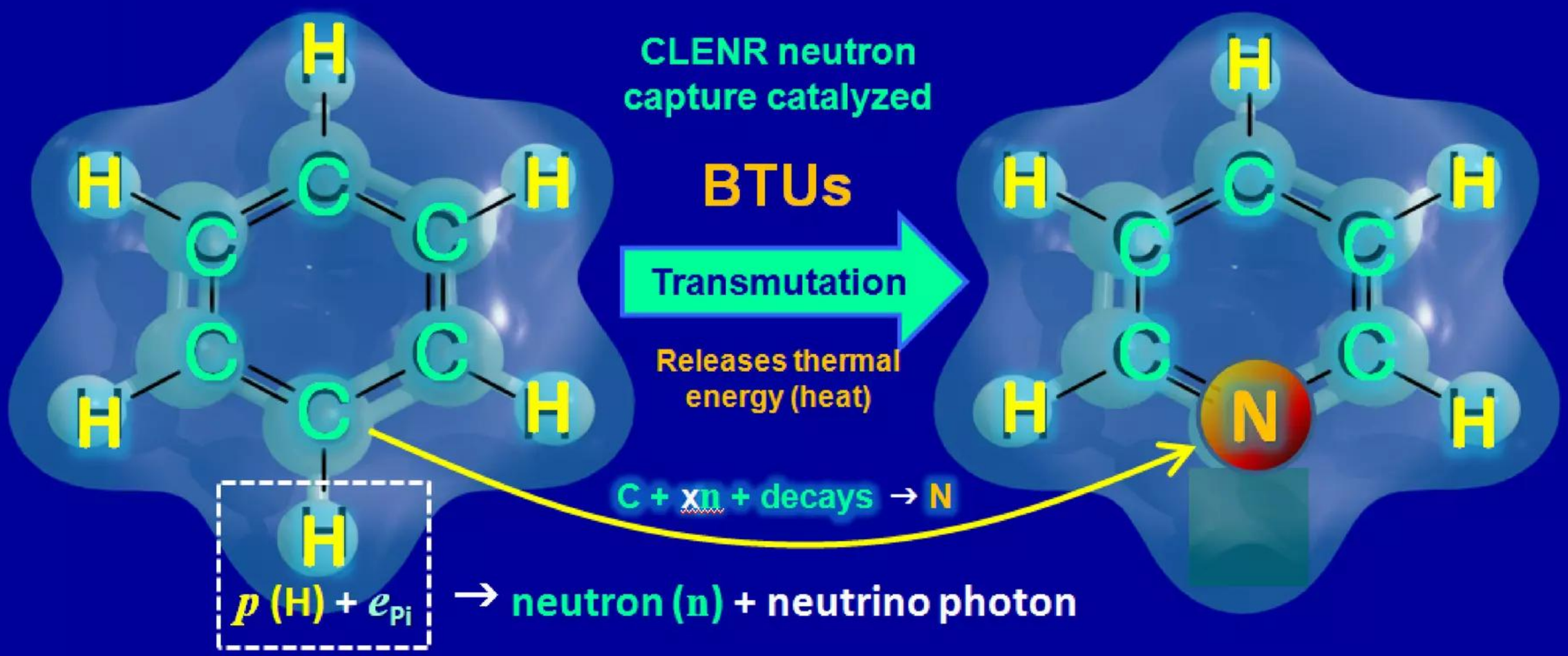
Lattice Energy LLC

Oil/coal aromatic fractions could become green LENR fuels

Carbon transmutation with neutrons creates benign stable elements

Hydrocarbon aromatic rings can serve as nanoscale CLENR reactors

Clean low energy neutron reactions (CLENRs) transmute Carbon C atoms into other stable elements without emitting deadly radiation or creating radwastes



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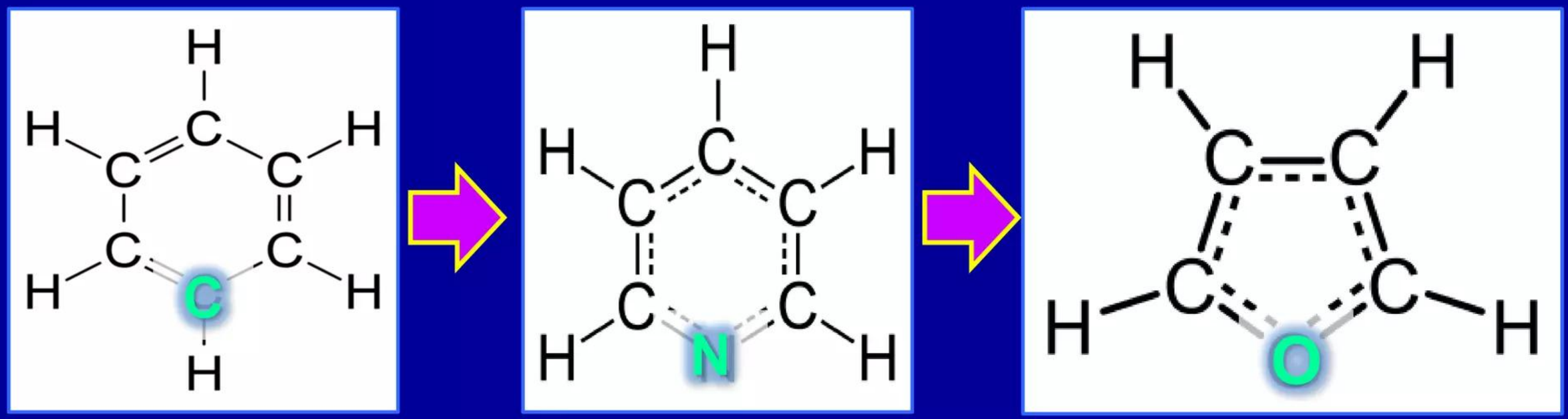
Oil/coal aromatic fractions could become green LENR fuels

Radiation-free green transmutation of Carbon → Nitrogen → Oxygen

LENR CNO 'cycle' can end at Nitrogen or Oxygen instead of making CO_2

Aromatic molecules' chemistry changes in parallel with Carbon transmutation



For details please see Lattice PowerPoint SlideShare document dated April 8, 2014 at:
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-converting-oil-and-coal-into-more-energetic-green-co2free-clenr-fuels-april-8-2014

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Number of patents involving LENR technology is growing

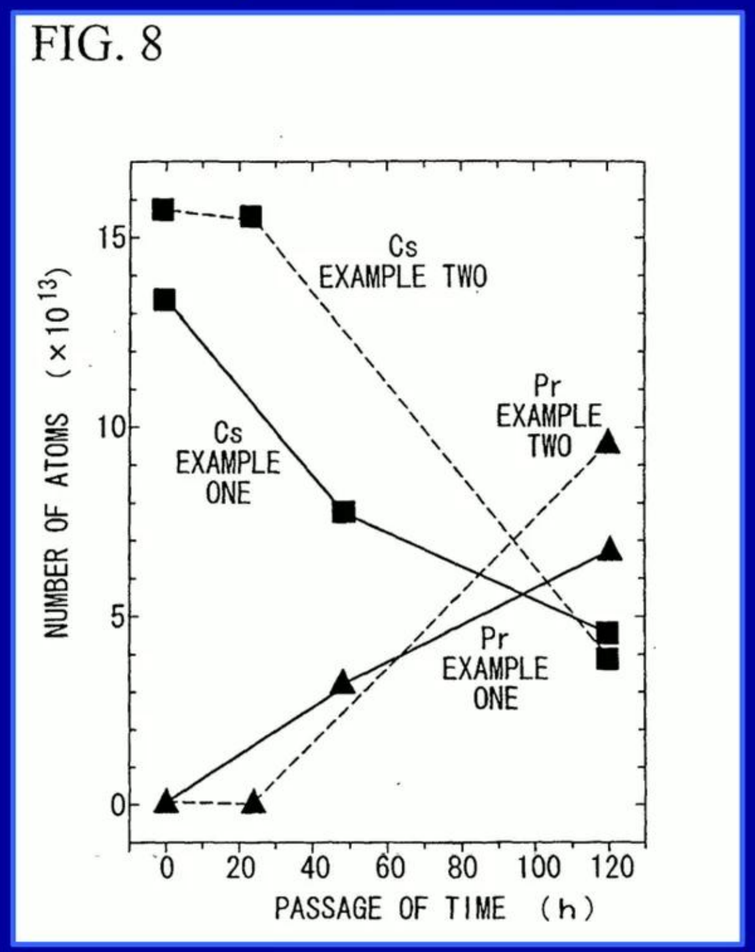
Mitsubishi Heavy Industries granted European patent on transmutation

EP 1202290 B1: "Nuclide transmutation device and nuclide transmutation method"

Inventors: Y. Iwamura and T. Itoh
Assignee: Mitsubishi Heavy Industries, Ltd.
PCT filing date: October 30, 2001
Issuance date: December 4, 2013
https://docs.google.com/viewer?url=patentimages.storage.googleapis.com/pdfs/1dc36049b9109cb93bf1/EP1202290B1.pdf

Abstract: "The present invention produces nuclide transmutation using a relatively small-scale device. The device that produces nuclide transmutation comprises a structure body that is substantially plate shaped and made of palladium (Pd) or palladium alloy, or another metal that absorbs hydrogen (for example, Ti) or an alloy thereof, and a material that undergoes nuclide transmutation laminated on one surface among the two surfaces of this structure body. The one surface side of the structure body, for example, is a region in which the pressure of the deuterium is high due to pressure or electrolysis and the like, and the other surface side, for example, is a region in which the pressure of the deuterium is low due to vacuum exhausting and the like, and thereby, a flow of deuterium in the structure body is produced, and nuclide transmutation is carried out by a reaction between the deuterium and the material that undergoes nuclide transmutation."

Shows transmutation of Cesium (Cs) into Praseodymium (Pr) over a period of ~120 hours



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Mitsubishi EP 1202290 B1 implicitly involves Widom-Larsen

Patent specification shows neutron production and capture on targets

Neutron captures make MeV gammas; heavy electrons convert γ into infrared

Mitsubishi's patent specification clearly describes LENR transmutation process as starting with creation of neutrons from protons or deuterons via weak interaction followed by successive neutron captures on targets and then decays which follow rows in Periodic Table to create stable nuclear transmutation products, i.e., other elements. This is what is explained rigorously by physics of the Widom-Larsen theory of LENRs; conversion of MeV gammas (invariably created as result of neutron captures) directly into benign infrared is taught in Lattice's US 7,893,414 B2. For example, see following items in EP 1202290 B1:

- ✓ **Page #9; lines #30 - 39: shows weak interaction that produces neutrons followed by neutron captures and products starting with a stable Cesium target (Cs)**
- ✓ **Page #10; lines #35 - 40: shows longer reaction sequence with LENR neutron-catalyzed transmutation of Carbon (C) targets into stable Sulfur (S)**
- ✓ **Page #12; lines #5 - 8: shows LENR neutron capture on Strontium (Sr) target which then gets transmuted into stable Molybdenum (Mo)**
- ✓ **Page #14; lines #52 - 55: shows LENR neutron capture on Sodium (Na) target to make end-product of stable Aluminum (Al)**

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Lattice has fundamental US patent on gamma suppression

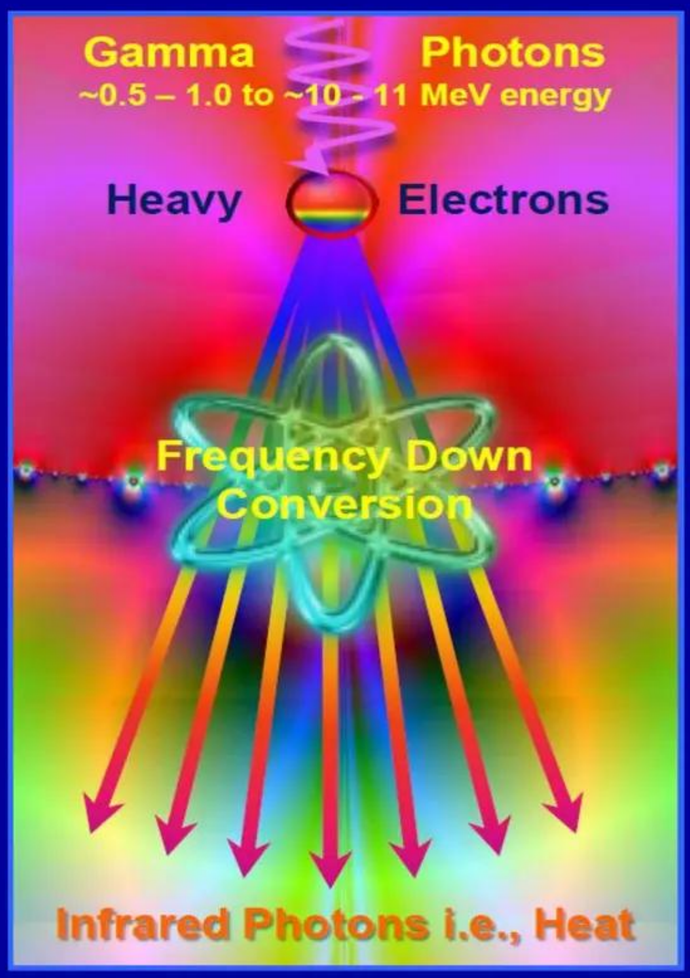
Covers LENR devices involving neutron-catalyzed nuclide transmutation

US 7,893,414 B2: "Apparatus and Method for Absorption of Incident Gamma Radiation and its Conversion to Outgoing Radiation at Less Penetrating, Lower Energies and Frequencies"

Inventors: L. Larsen and A. Widom
Assignee: Lattice Energy LLC
U.S. filing date: September 9, 2005
Issuance date: February 22, 2011
http://www.slideshare.net/lewisglarsen/us-patent-7893414-b2

Abstract: "Gamma radiation is shielded by producing a region of heavy electrons and receiving incident gamma radiation in such region. The heavy electrons absorb energy from the gamma radiation and re-radiate it as photons at a lower energy and frequency. The heavy electrons may be produced in surface plasmon polaritons. Multiple regions (6) of collectively oscillating protons or deuterons with associated heavy electrons may be provided. Nanoparticles of a target material on a metallic surface capable of supporting surface plasmons may be provided. The region of heavy electrons is associated with that metallic surface. The method induces a breakdown in a Born-Oppenheimer approximation. Apparatus and method are described."

Deadly emitted gamma photons converted into benign infrared heat



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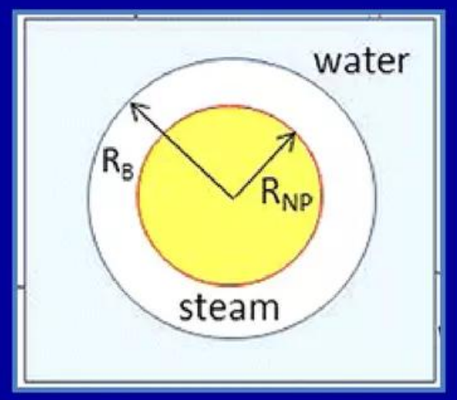
Nanotechnologists are making many amazing discoveries

LENRs + nanotech perhaps vault steam technology into 21st century

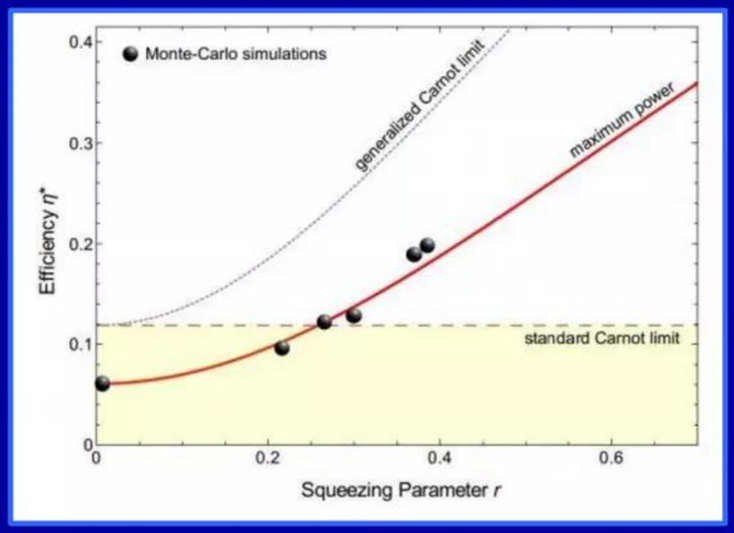
Microscopic LENR-active surface sites beg for application of new nanotech

Technical teasers: more efficient steam generation and maybe breaking Carnot limit

"Evolution of light-induced vapor generation at a liquid-immersed metallic nanoparticle"
Z. Fang *et al.*
Nano Letters 13 pp. 1736 - 1742 (2013)
http://pubs.acs.org/doi/abs/10.1021/nl4003238



"Nanoscale heat engine beyond the Carnot Limit"
J. Roßnagel *et al.*
Physical Review Letters 112 pp. 030602 - 030607 (2014)
http://prl.aps.org/abstract/PRL/v112/i3/e030602



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Additional reading for the technically inclined

Lattice document that provides a broad-based overview about LENR technology and its potential:

"Truly green nuclear energy exists – an overview for everybody: no deadly gammas … no energetic neutrons … and no radioactive waste"
L. Larsen, Lattice Energy LLC, v. 5 updated and revised through March 5, 2014 [108 slides]

http://www.slideshare.net/lewisglarsen/powering-the-world-to-a-green-lenr-future-lattice-energy-llcapril-11-2013

Index to large collection of documents about LENR theory, experimental data, and the technology:

"Index to key concepts and documents" v. #17
L. Larsen, Lattice Energy LLC, May 28, 2013 [113 slides] Updated and revised through January 12, 2014

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

Review paper that covers all theoretical aspects of basic Widom-Larsen theory published to date:

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen, *Pramana - Journal of Physics* 75 pp. 617 - 637 (2010)

Abstract: "Under special circumstances, electromagnetic and weak interactions can induce low-energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow-moving electrons can (under appropriate circumstances) be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low-energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analyzed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them."

http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

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Commercializing a next-generation source of green nuclear energy

By the world very gradually switching power generation technologies from presently dominant chemical combustion processes and instead going down the new LENR transmutation route and by using green LENR fuels derived directly from petroleum and coal, we have an opportunity to dramatically extend the effective longevity of today's dense energy resources. Achieving this goal would postpone mankind's day of reckoning on having abundant, very affordable supplies of dense, nonpolluting, CO_2-free energy sources for perhaps thousands of years.

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Commercializing a next-generation source of green nuclear energy

“We choose to go to the Moon in this decade and do the other things, not because they are easy - but because they are hard.

Because that challenge is one we are willing to accept, one we are unwilling to postpone - and one we intend to win.”

U.S. President John F. Kennedy
Speech at Rice University, Houston, Texas (1962)

Empire of the Sun - “Walking on a Dream” 3 min. 20 sec. video
http://www.youtube.com/watch?feature=player_detailpage&v=eimgRedLkkU