

# Consideration of LENR for Aircraft Propulsion (15ATC-0399)

Session ATC502 - Business/Economics - Future Propulsion Technology

David L. Daggett, Ph.D., President

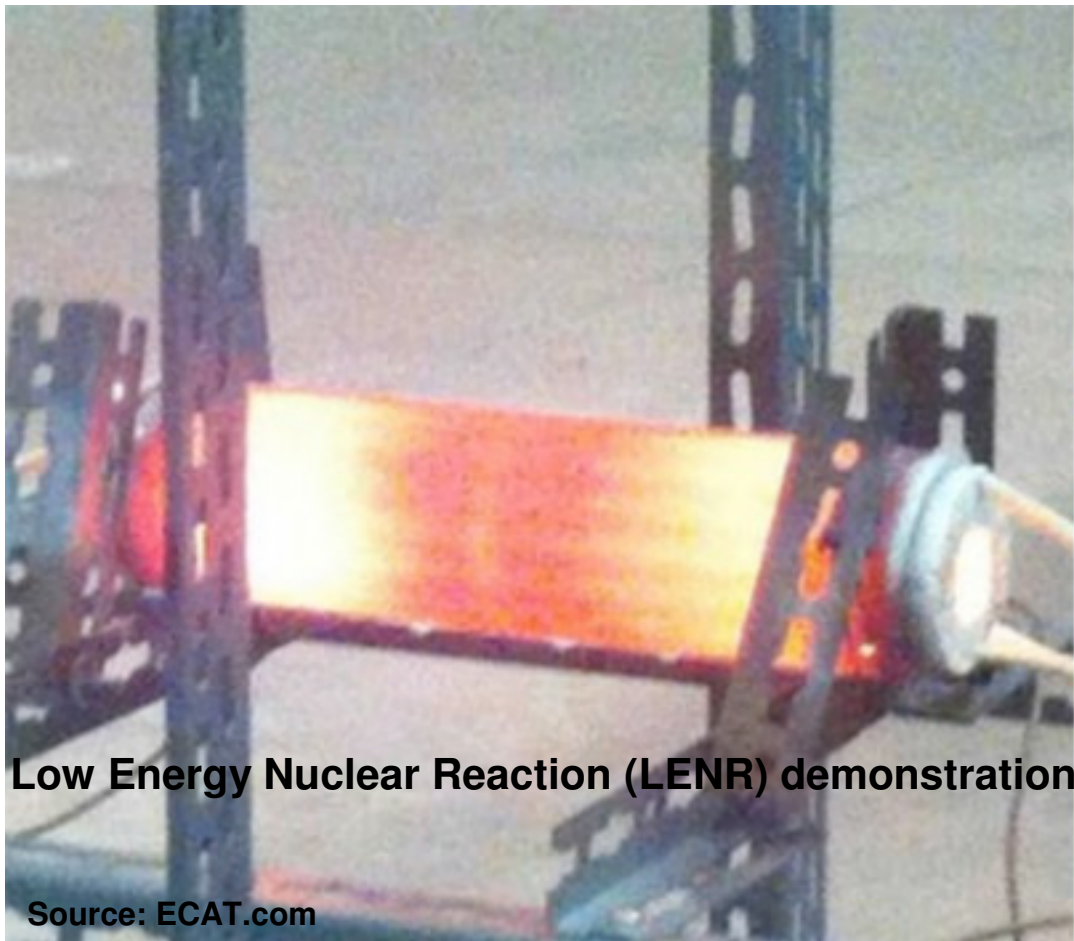
John Patterson, Chief Electrical Engineer

Katy Goloborodov, Engineering Intern



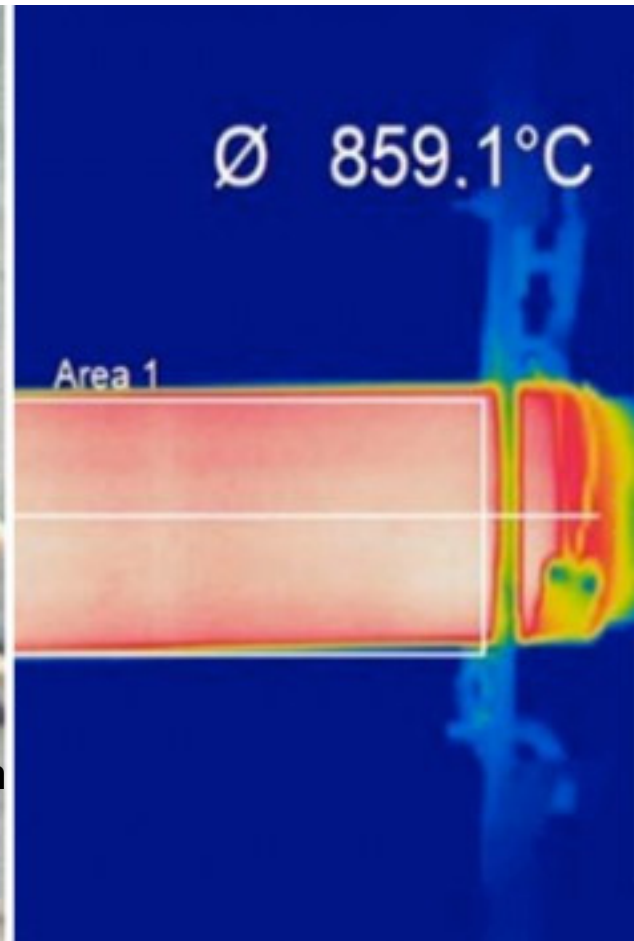
# What if ...

... claims of a clean energy breakthrough are true?



Low Energy Nuclear Reaction (LENR) demonstration

Source: ECAT.com



LENR would be a world changing technology... for aviation too.



(1)  
1 Barrel of Ni-H fuel  
=  
1 Supertanker of oil

ECAT.com - LENR Energy

(1) Nickel-Hydrogen is the fuel used in ECAT's LENR reactor

# Agenda

- **Introduction to LENR**
- **Design considerations & enabling technology**
- **Proposed Hybrid LENR propulsion system**
- **Summary**



## LENR background

**March 1989 - Prof Pons and Fleishman announce “excess heat” in electrochemistry experiments.**

**DOE engages prestigious researchers to perform superficial evaluations**

**The press coins term “cold fusion”**

**Repeatability issues preclude validation by 3rd parties**

**Nov 1989 – DOE issues negative report**

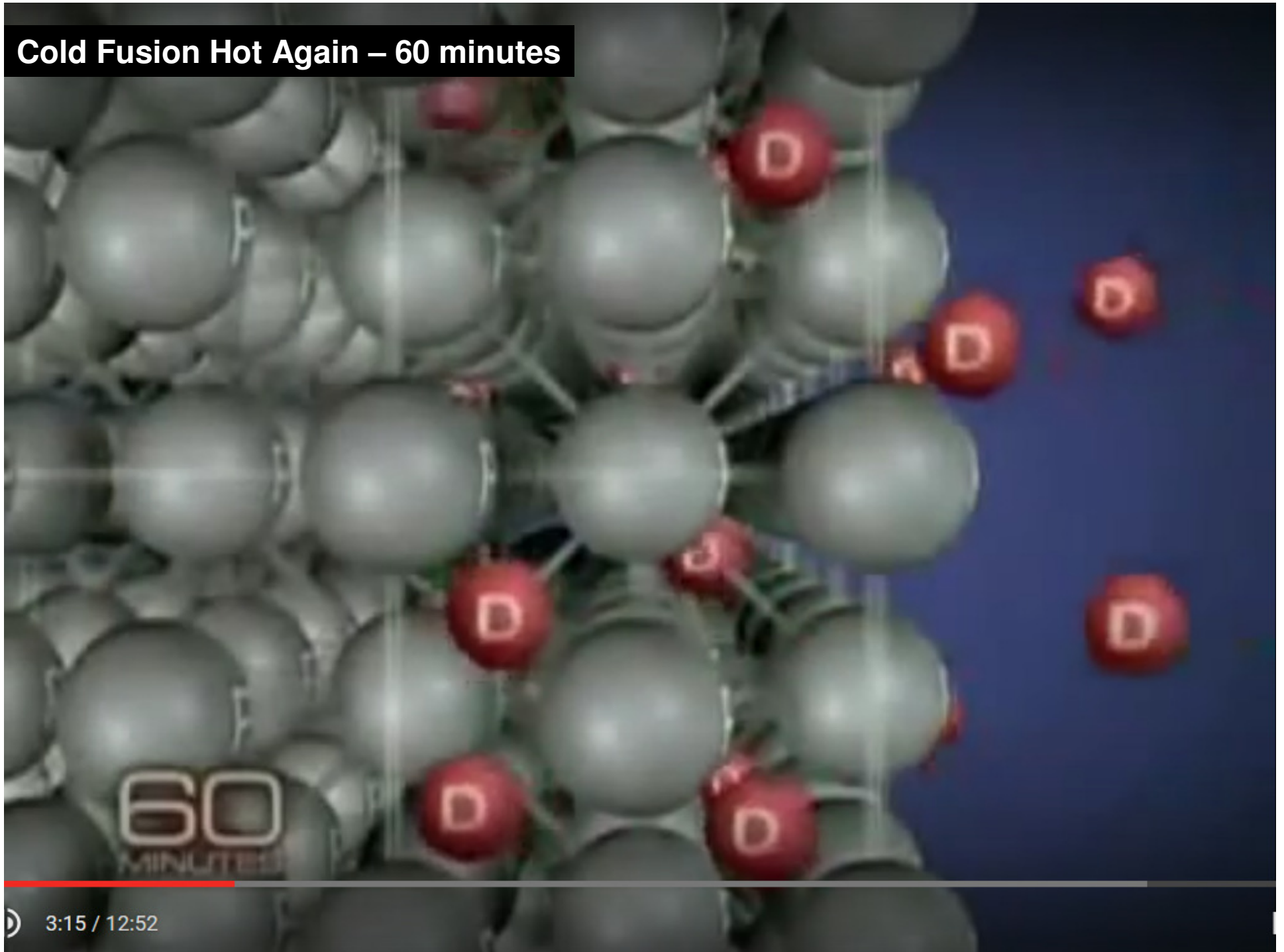
**March 1990 – Nature publication says “farewell” to cold fusion**



Source: C. Beaudette “Excess Heat”

Source: NYtimes.com

## Cold Fusion Hot Again – 60 minutes



60  
MINUTES



# Andrea Rossi's E-cat progress

**E-cat 1MW prototype**



Andrea-Rossi.com



**Tom Darden of  
Industrial Heat funds  
Rossi's work**



## Bill Gates briefed on LENR by Dr. Vittorio Violante at the ENEA\* labs in Frascati, Italy



\* The Italian National Agency for New Technologies, Energy and Sustainable Economic Development

# Rob Duncan (VP of Research) recently founded Center for Emerging Energy Sciences (CEES) at Texas Tech for R&D of LENR



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### Welcome to Texas Tech Research

Welcome to the website for the Vice President for Research (OVPR) at Texas Tech University in Lubbock!

The office exists to foster an academic environment in which research, instruction, service, and economic development missions are permeated by the joy and rigor of original discovery, creativity, innovation and scholarship.

The OVPR has dedicated staff who work hard to support three main goals:



# Airbus appears to support LENR as evidenced on their Chief Scientist's LinkedIn Page



**Jean-Francois Geneste**

Vice-President Chief Scientist at Airbus Group

Follow

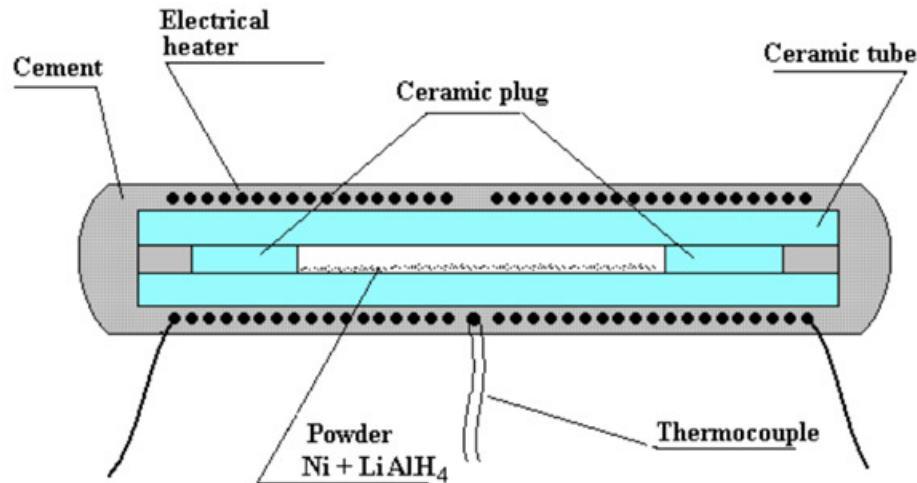
## Major breakthrough in the field of energy

Aug 13, 2015 | 332 views | 16 Likes | 6 Comments |   

I made a major theoretical breakthrough in the field of "energy creation". This will be presented at the 11th workshop on anomalies in hydrogen loaded metals which will be held next October in Airbus, Toulouse. <http://www.iscmns.org/work11/>.

What it basically consists in is a global theorization of energy creation which includes all known means up today, that they be chemical, nuclear fission or nuclear fusion. Against all expectations, it is proved that there is potential room for **cold fusion** or so in a breakthrough approach of building a "burner" and making a (new) fuel. As a consequence, even if the burden of proof remains to cold fusionists to experimentally prove, at least, they are right, on a theoretical

# Alex Parkhomov replicates E-cat experiments



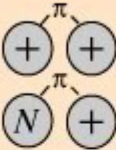
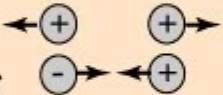

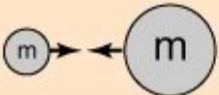
Mean temperature of a mode	°C	970	1150	1290
Duration of a mode	min	38	50	40
Electrical heating power	W	300	394	498
Electrical energy consumption	J	684000	1182000	1195200
Evaporating water mass	kg	0,2	0,8	1,2
Energy spend on evaporation	J	452000	1808000	2712000
	W	155	155	155
Heat outflow through the thermal insulation	J	353400	465000	372000
	W	155	155	155
Total produced energy	J	805400	2273000	3084000
Relation of produced heat to consumed energy		1,18	1,92	2,58

For 1 gram of Ni powder  
2.58X more energy out than input

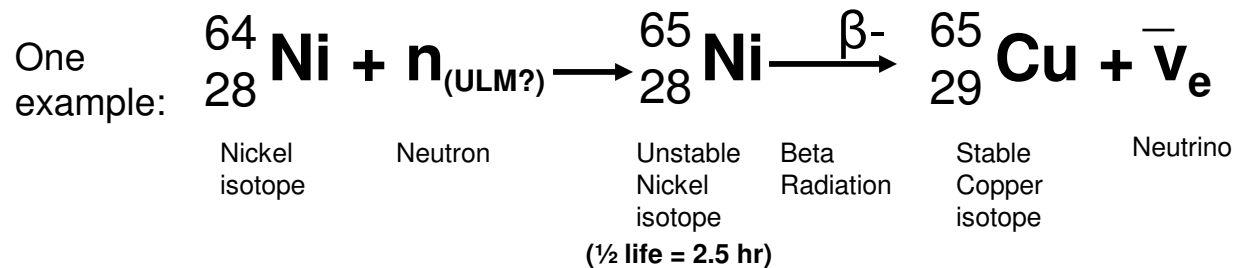
<http://www.infinite-energy.com/images/pdfs/ParkhomovEnglish.pdf>

# LENR would be classified as a weak (nuclear) force

Force figure: <http://alpcentauri.info>

Fundamental Forces					
<i>Strong</i>		Force which holds nucleus together	Strength <b>1</b>	Range (m) $10^{-15}$ (diameter of a medium sized nucleus)	Particle gluons, $\pi$ (nucleons)
<i>Electro-magnetic</i>			Strength $\frac{1}{137}$	Range (m) Infinite	Particle photon mass = 0 spin = 1
<i>Weak</i>		neutrino interaction induces beta decay	Strength $10^{-6}$	Range (m) $10^{-18}$ (0.1% of the diameter of a proton)	Particle Intermediate vector bosons $W^+$ , $W^-$ , $Z_0$ , mass > 80 GeV spin = 1
<i>Gravity</i>			Strength $6 \times 10^{-39}$	Range (m) Infinite	Particle graviton ? mass = 0 spin = 2

The decay of specific nuclear particles results in transmutation, resulting in the release of energy



## Power density of LENR fuel is 108\* times higher than jet fuel in Parkhomov demonstration

Jet-A	LENR Ni
18,500 BTU/lb	3,084,000 J of power produced in 40 min = 1285 W (4385 BTU) 1285 W/ 1 gram Ni (4385 BTU/ 0.0022 lb) = 1285 W/g (1,993,182 BTU/lb)

$$1,993,182 \text{ BTU/lb} / 18,500 \text{ BTU/lb} = 108$$

or 108X higher than Jet-A\*

*\* Probably much higher as experiments were terminated before fuel was exhausted.*

# Cost of LENR heat is 40X cheaper\* than Jet-A in Parkhomov's experiment

## Jet-A

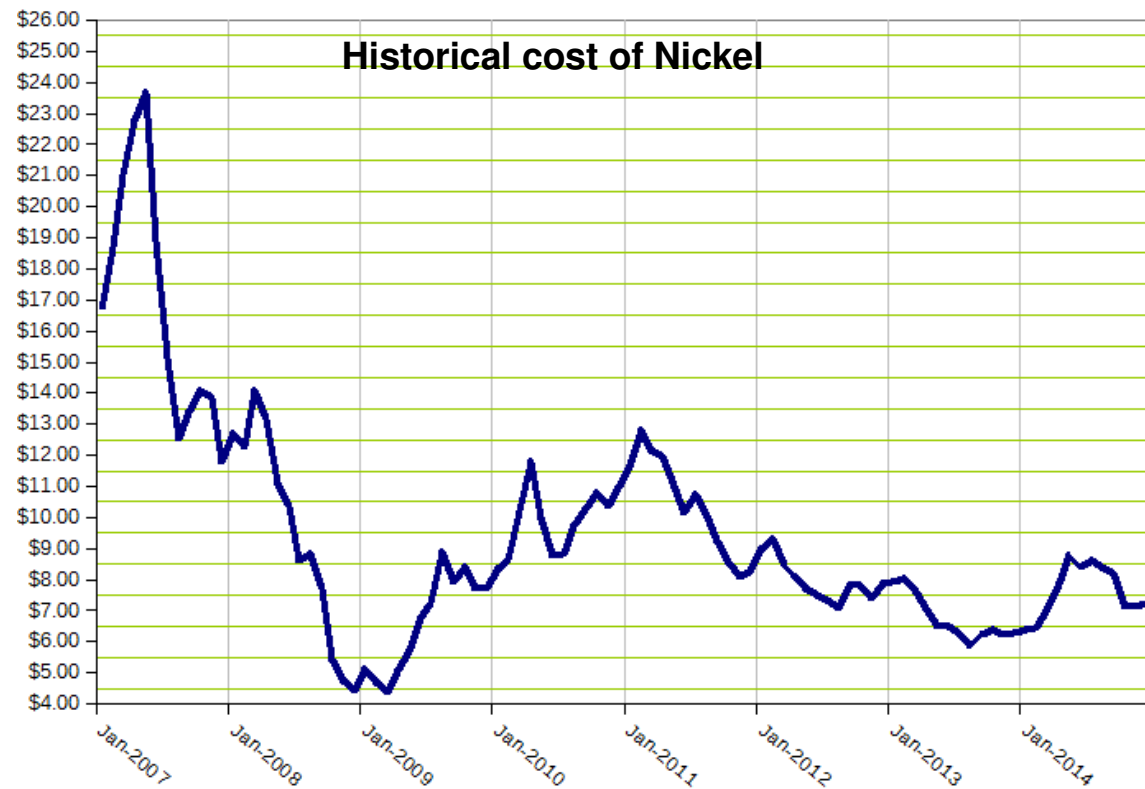
18,500 BTU/lb  
6.72 lb/gal  
\$3/gal  
= \$0.000024 per BTU

## LENR

1,993,182 BTU/lb  
\$12.00 per lb  
= \$0.0000006 per BTU

$$\frac{\$0.000024 \text{ per BTU}}{\$0.0000006 \text{ per BTU}} = 40X$$

*\* Probably much less as experiments were terminated before fuel was exhausted.*





# Agenda

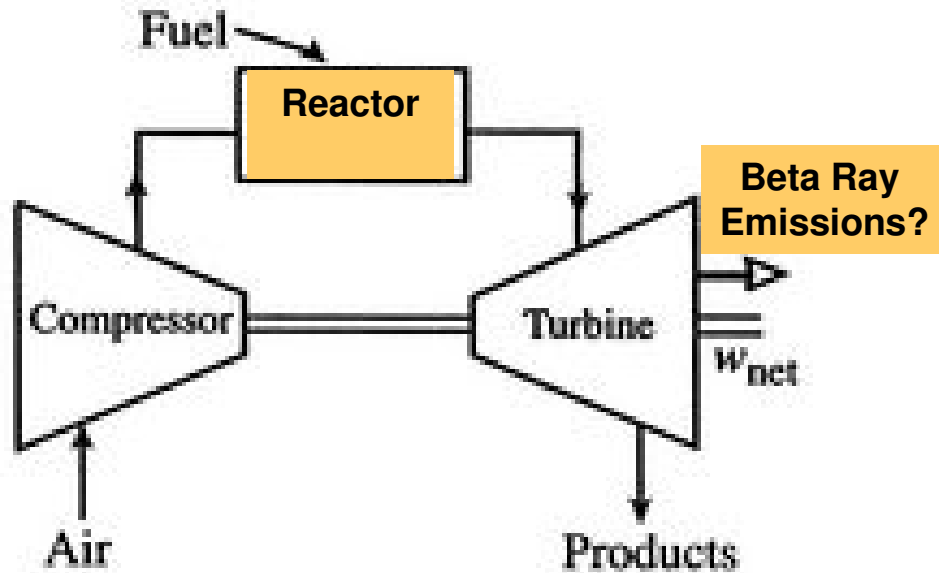
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# Design considerations for LENR aircraft propulsion

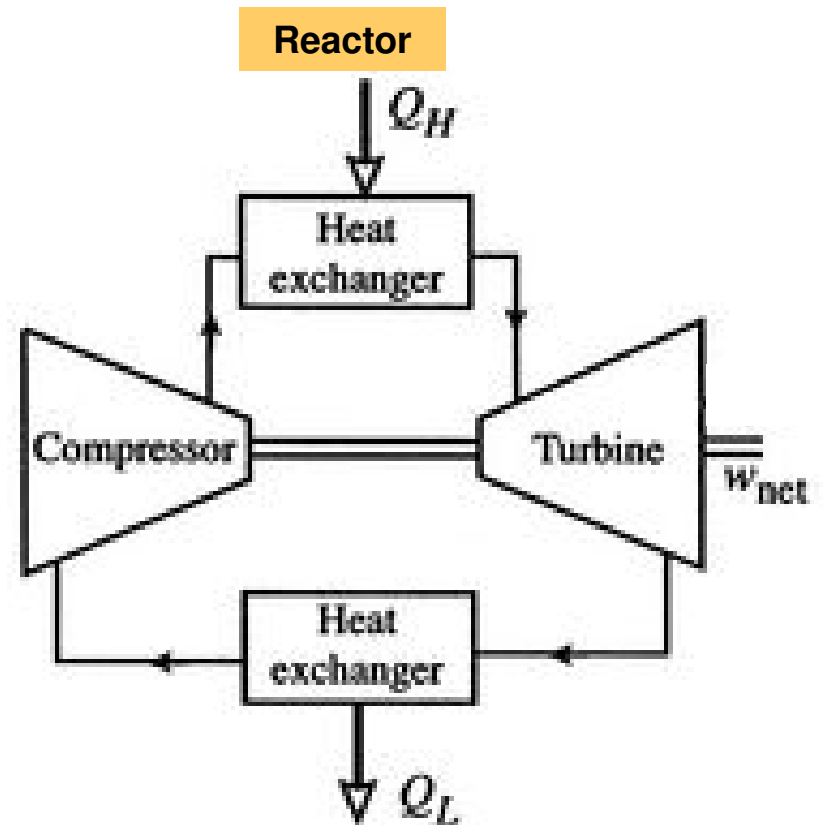
Airplane Requirements	Powerplant Factors	LENR vs. Turbofan
Safety	Lowest Failure Rate Achievable, Redundancy, Mishap Impact	Perhaps safer as no liquid fuel spills, need to design for no reactor breach
Economics	Cost, Reliability, Low Maintenance	Very high development cost, very low operating cost, better reliability and maintenance due to lower operating temperatures
Performance	Weight, Range, Power, Throttle Response	Unknown system weight, unlimited range, refueling every 6 months, hybrid system required for good <b>throttle response</b>
Regulations & Public Acceptance	Certification, Non-nuisance	New certification needed, LENR name needs to be replaced for public acceptance
Environmental	Emissions, Noise	Zero emissions when used in <b>closed cycle</b> system, much lower noise

# Closed cycle may be needed to eliminate any reactor emissions

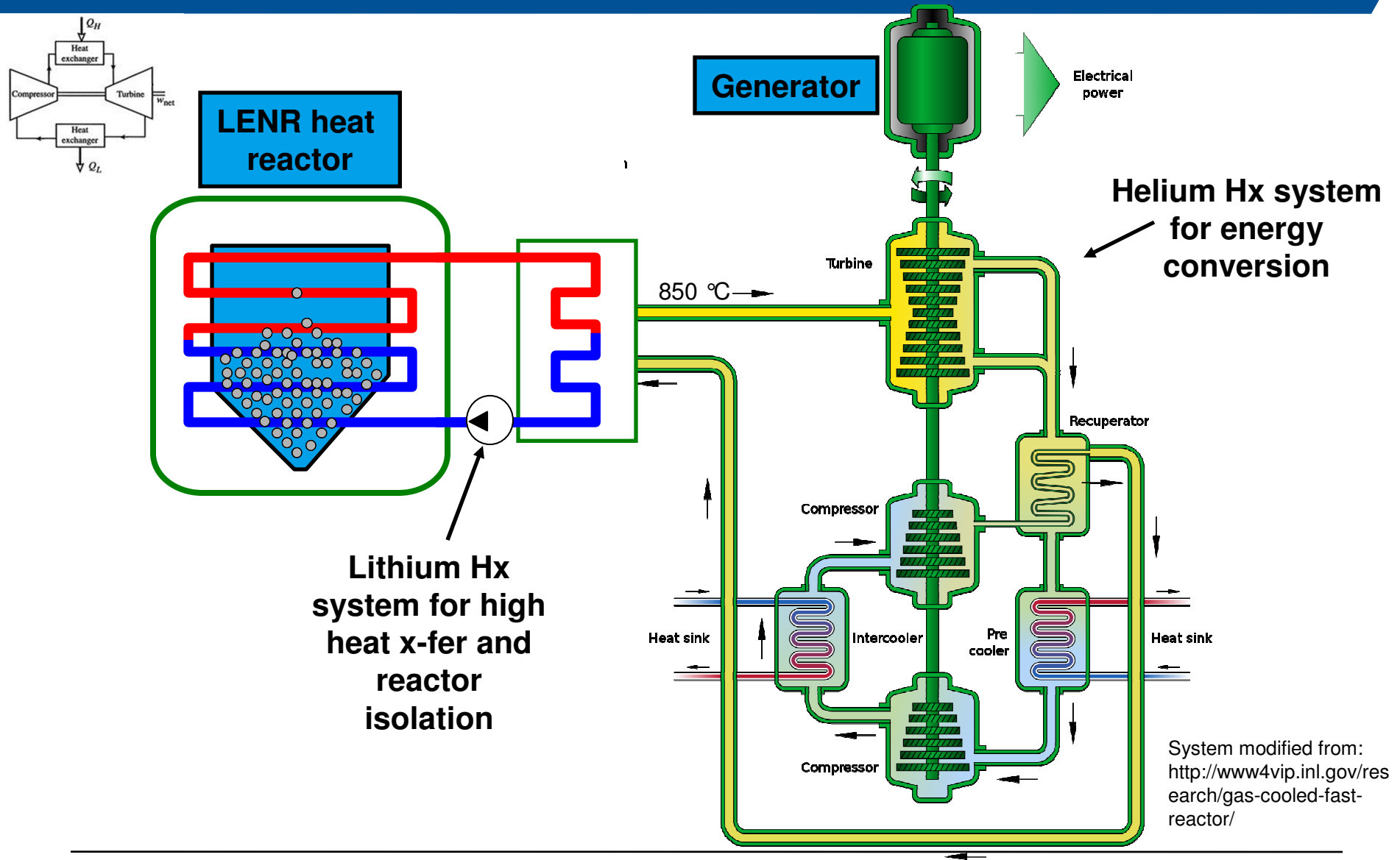
Open Cycle



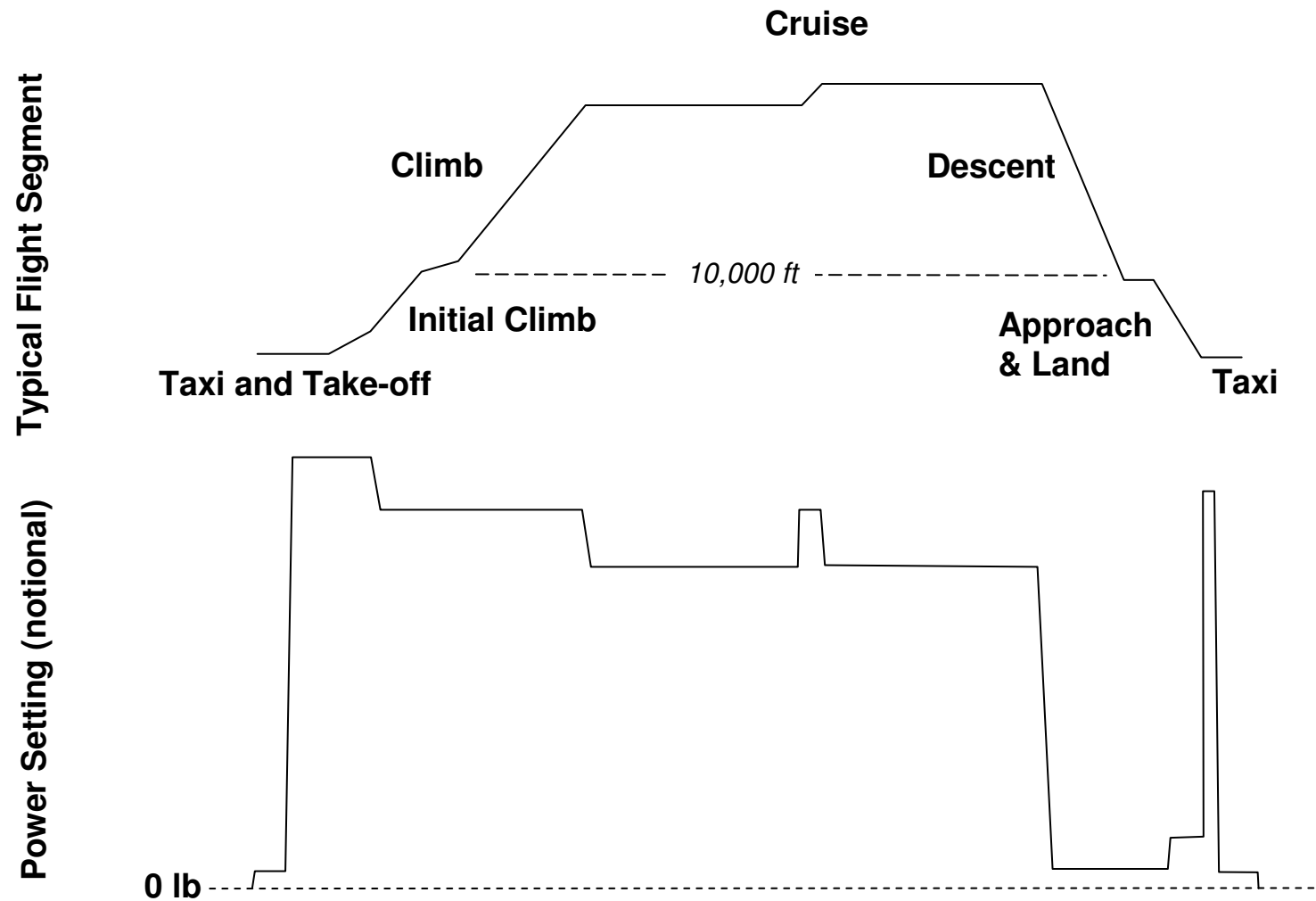
Closed Cycle



# Helium Gas-Cooled Fast Reactor (GFR) support system could be considered with a LENR reactor for an aircraft hybrid propulsion system

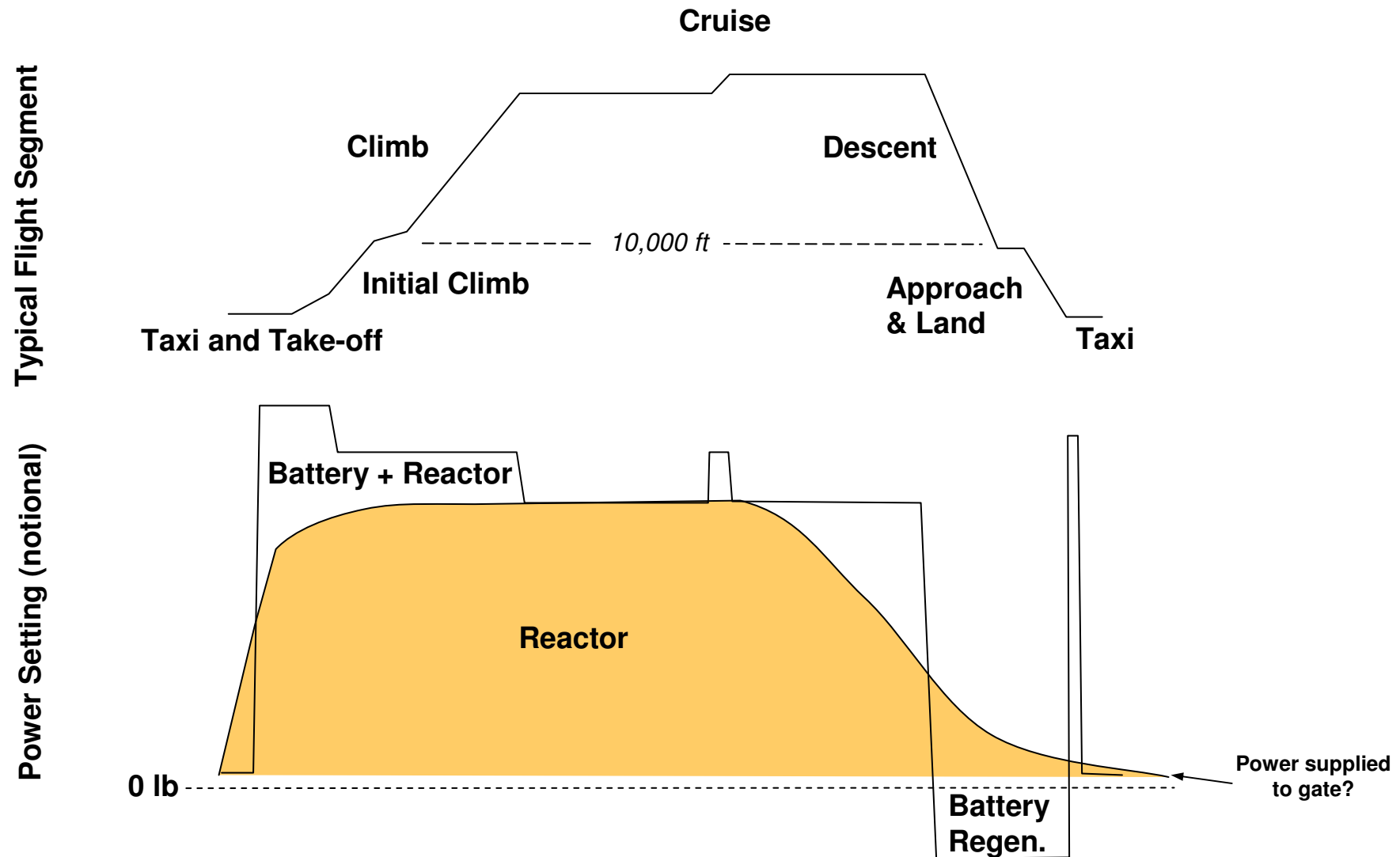


# Aircraft need fast throttle response





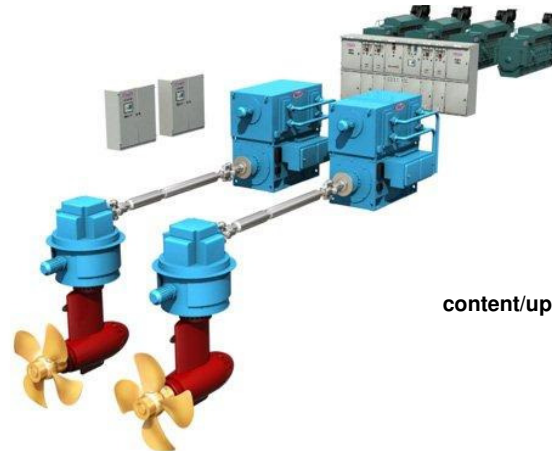
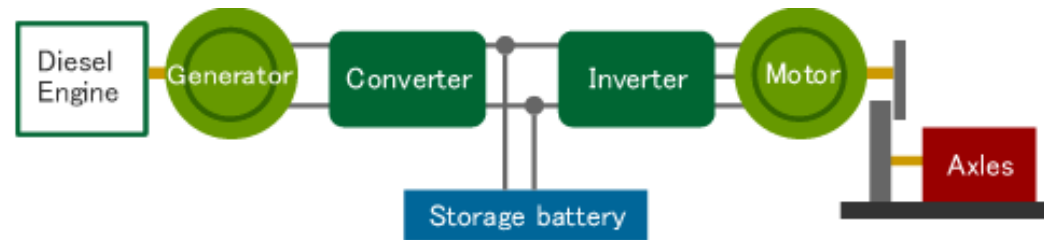
# Hybrid system would make up for slow reactor response



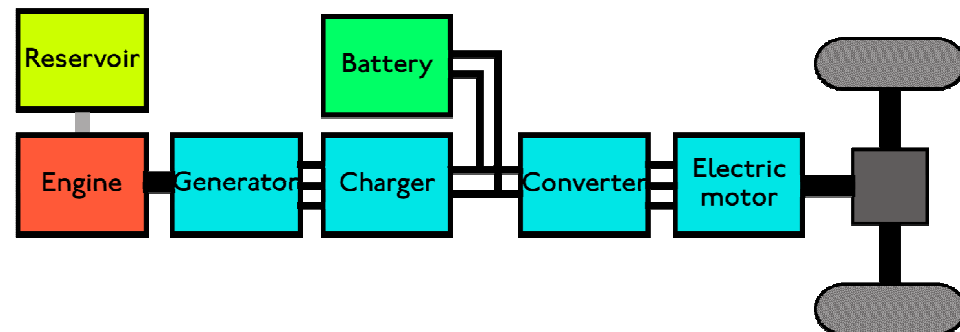
# Use well-proven hybrid technologies from other transports for aircraft design



<http://www.hitachi-rail.com/products/on-board/propulsion/hybrid/feature01.html>



Source: <http://gcaptain.com/wp-content/uploads/2011/11/stadt-samsung-hybrid-ship-propulsion.png>



Source: [https://en.wikipedia.org/wiki/Chevrolet\\_Volt](https://en.wikipedia.org/wiki/Chevrolet_Volt)

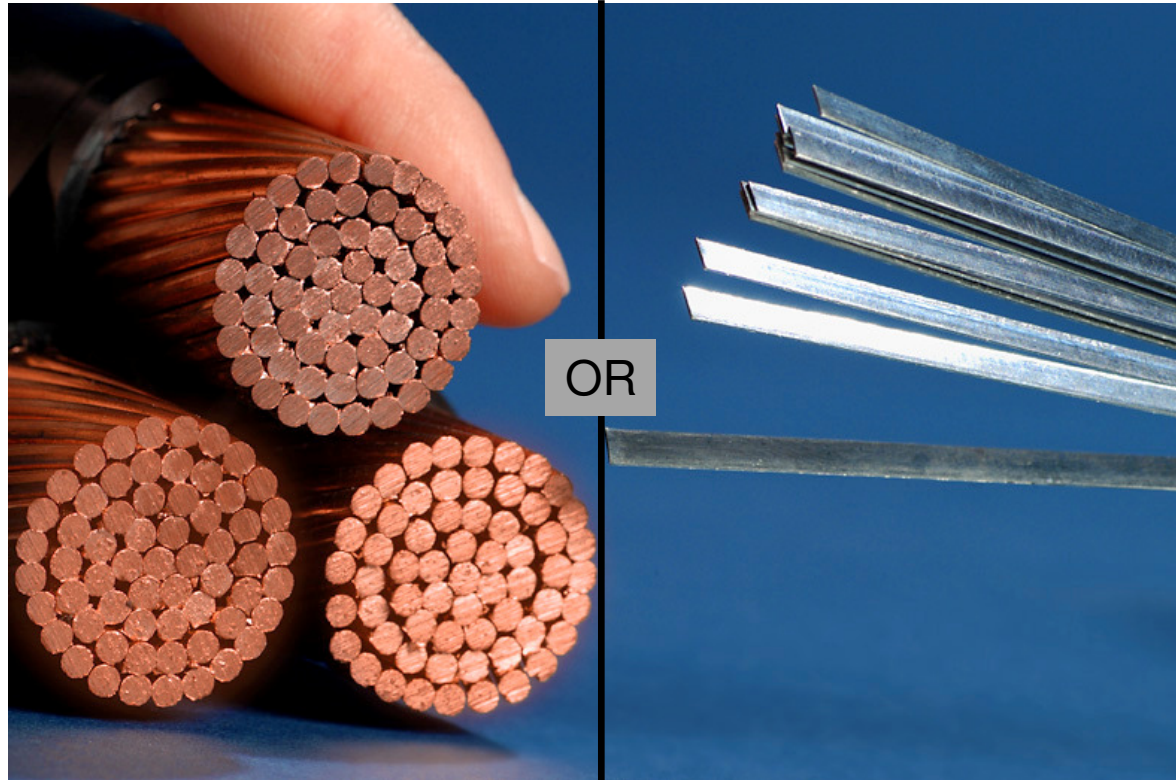
## Advanced batteries would also be an enabling technology for a hybrid aircraft



**SUGAR Volt battery powered airplane concept**

Source: [http://www.boeing.com/aboutus/environment/environment\\_report\\_14/img/2\\_defining/3\\_future\\_flight/2.3.2\\_sugar\\_volt.jpg](http://www.boeing.com/aboutus/environment/environment_report_14/img/2_defining/3_future_flight/2.3.2_sugar_volt.jpg)

# High Temperature Super Conductors are required to reduce hybrid system weight



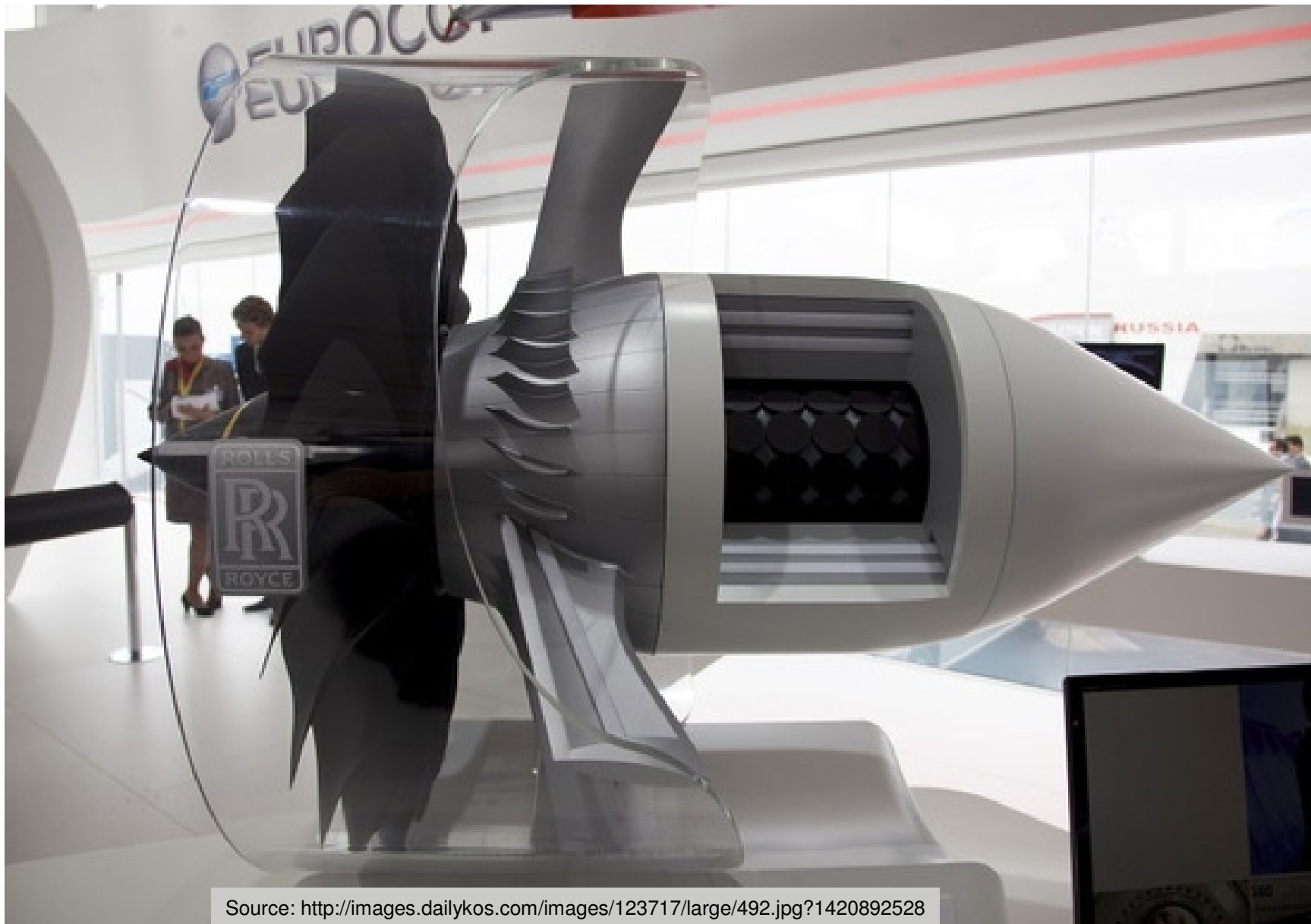
Copper

High temperature (LN<sub>2</sub>)  
super conductors

Source: Amercian Superconductor



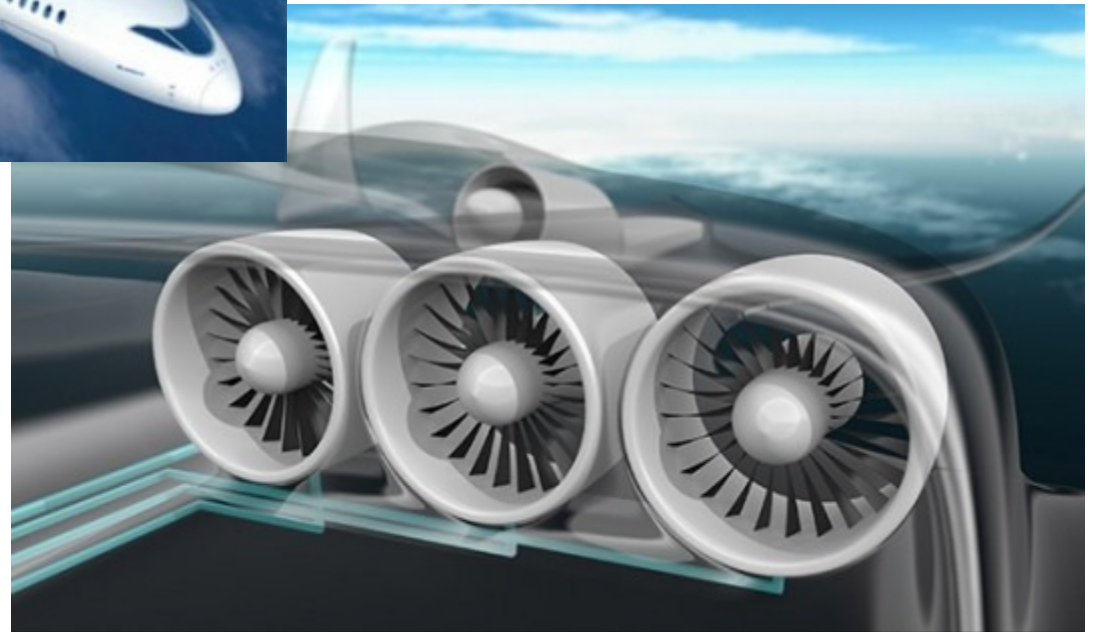
## Electric aircraft motor studies will support LENR-powered architectures



Source: <http://images.dailykos.com/images/123717/large/492.jpg?1420892528>



# Electric propulsion will allow a plethora of aircraft designs for reduced noise and improved environmental performance

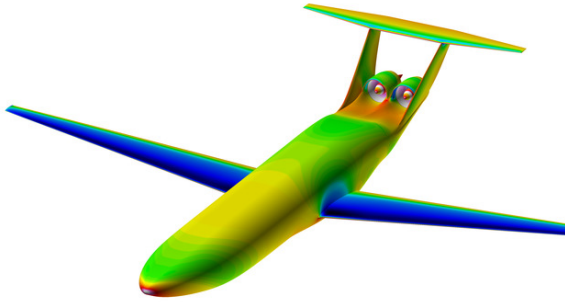


Source: <http://www.airbusgroup.com/int/en.html>

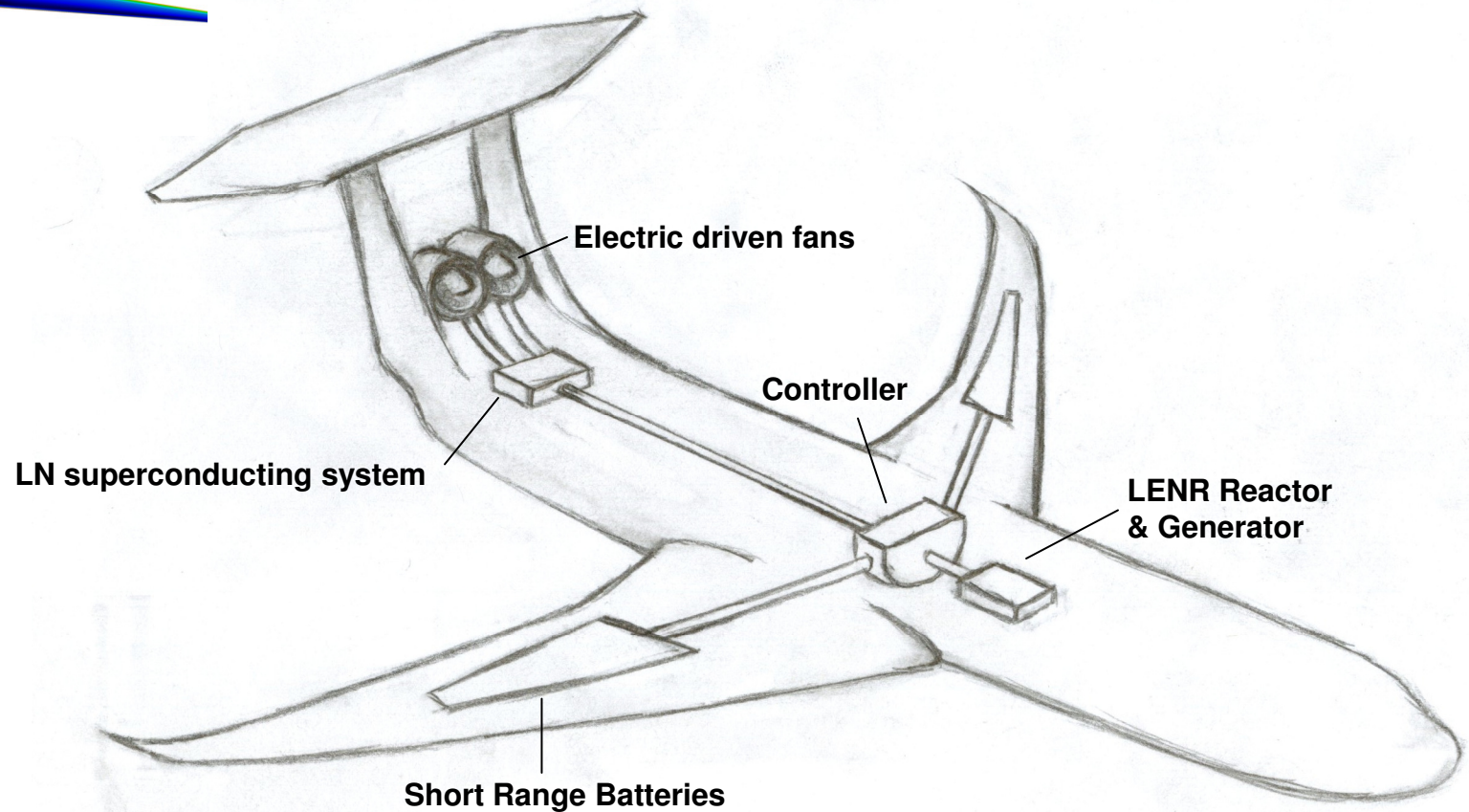
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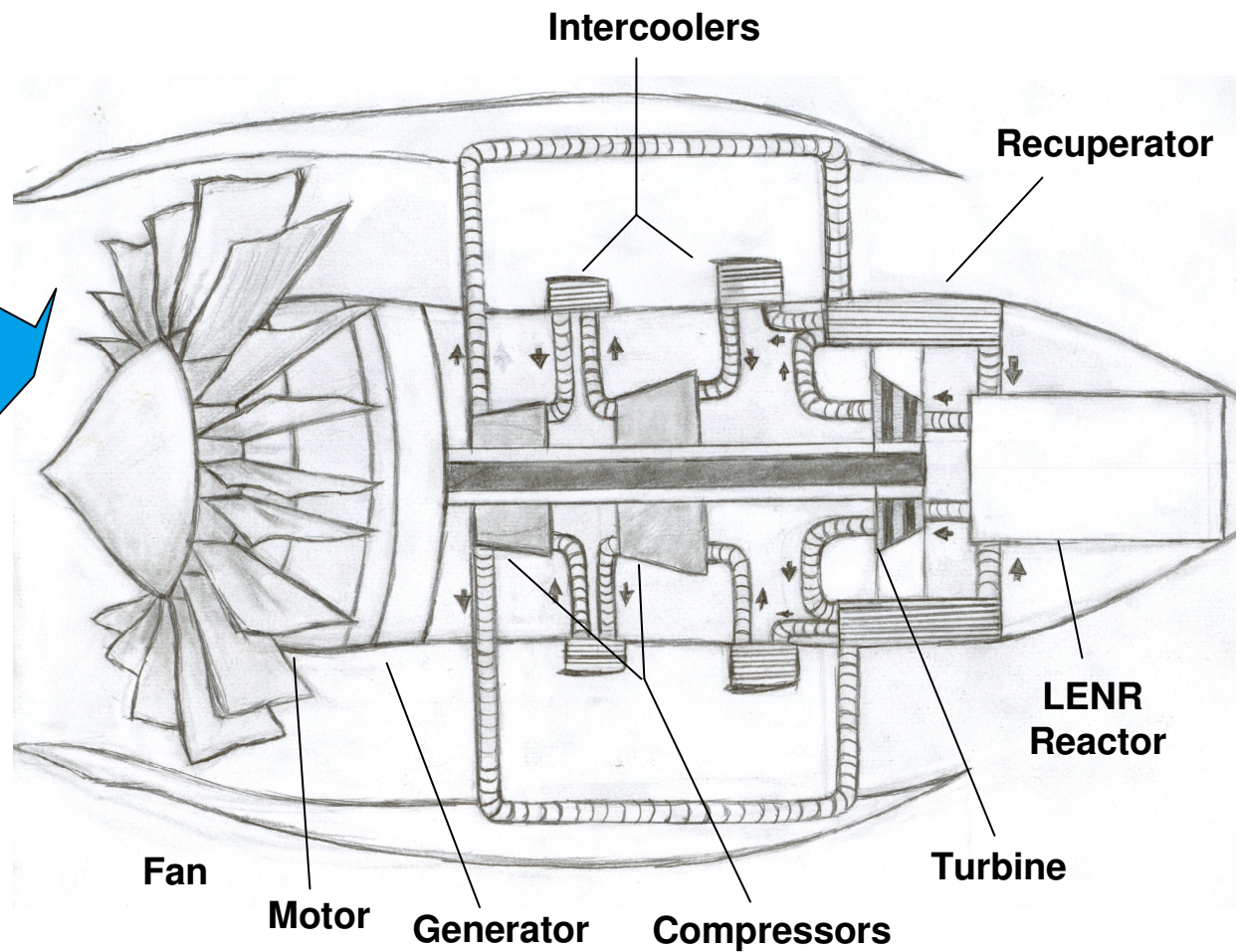
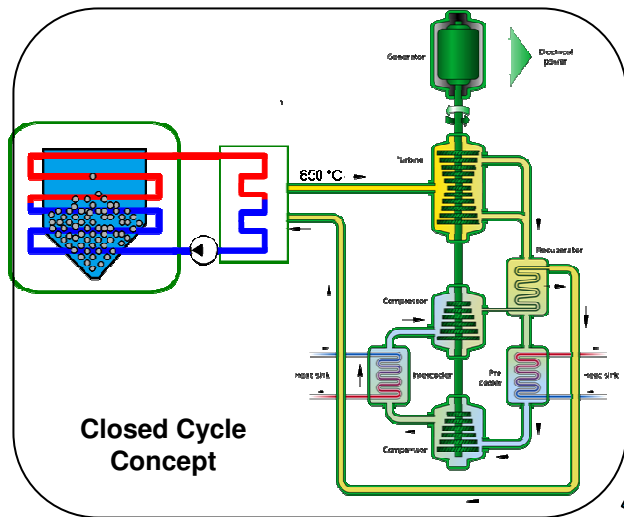
# Option 1: Central Power Supply Architecture Arrangement



Source: NASA



## Option 2: Engine-Mounted LENR Concept





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# LENR is:

- Promising
- An Enabling Technology
- Economically Game-Changing

*Further Investigation is warranted*

SAE INTERNATIONAL



Phonon Energy's LENR Test Rig

**Thank you**

**Questions?**