Distant Nuclear Fusion

By John Benson

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1. Introduction

When we look up at night and view the stars, everything we see is shining because of distant nuclear fusion.

— Carl Sagan, Cosmos (1980, p. 238)

I have been posting papers to Energy Central since 2017, and weekly posts since 2018. During this time, I have occasionally come across a subject and considered writing a post on it. The reason I haven't is because, even though it is an advanced technology for producing energy, it will not produce any usable electric power for decades.

There are currently two experiments that are designed to reach "break-even" fusion within the next several years, but this means that the experiment will inject as much energy into the inner, or core process as comes out in the form of high energy neutrons. Forget any energy-conversion efficiencies outside of the core – no electric energy will come out of these initial facilities in spite of huge amounts going in.

One of these two projects, the International Thermonuclear Experimental Reactor (ITER) is in Saint-Paul-lez-Durance, France. The other, the National Ignition Facility (NIF) is here in my home town of Livermore, California.

ITER is scheduled to turn on in 2025, and reach full power by 2035. NEF has been running for over a decade. ITER cost $25 billion. The cost of NIF is a bit difficult to parse. The official cost is $3.5 billion, but there were several earlier experiments that led up to NIF, and NIF has been expanded and modified since it was commissioned in 2009.

If, at some point in the distant future some fusion machine is built that is financially viable (for producing power), it will look nothing like either of these machines. These are both hand-built experiments, each made from solid unobtainium. Their jobs are to teach us about the core processes of fusion and how to efficiently ignite and control it in a manner that might produce continuous operation and electric power.

2. ITER

ITER is a Tokamak Design. The heart of a Tokamak is its toroidal-shaped vacuum chamber with a (roughly) D-shaped cross section

Inside, under the influence of extreme heat, gaseous hydrogen fuel becomes a plasma—a hot, electrically charged gas. In a fusion device, plasmas provide the environment in which deuterium and tritium (the second and third isotope of hydrogen) can fuse and yield energy. [1]

Normal hydrogen contains a proton and an electron, deuterium adds a single neutron, and tritium adds two neutrons.

The charged particles of the plasma can be shaped and controlled by the massive magnetic coils placed around the vessel; physicists use this important property to

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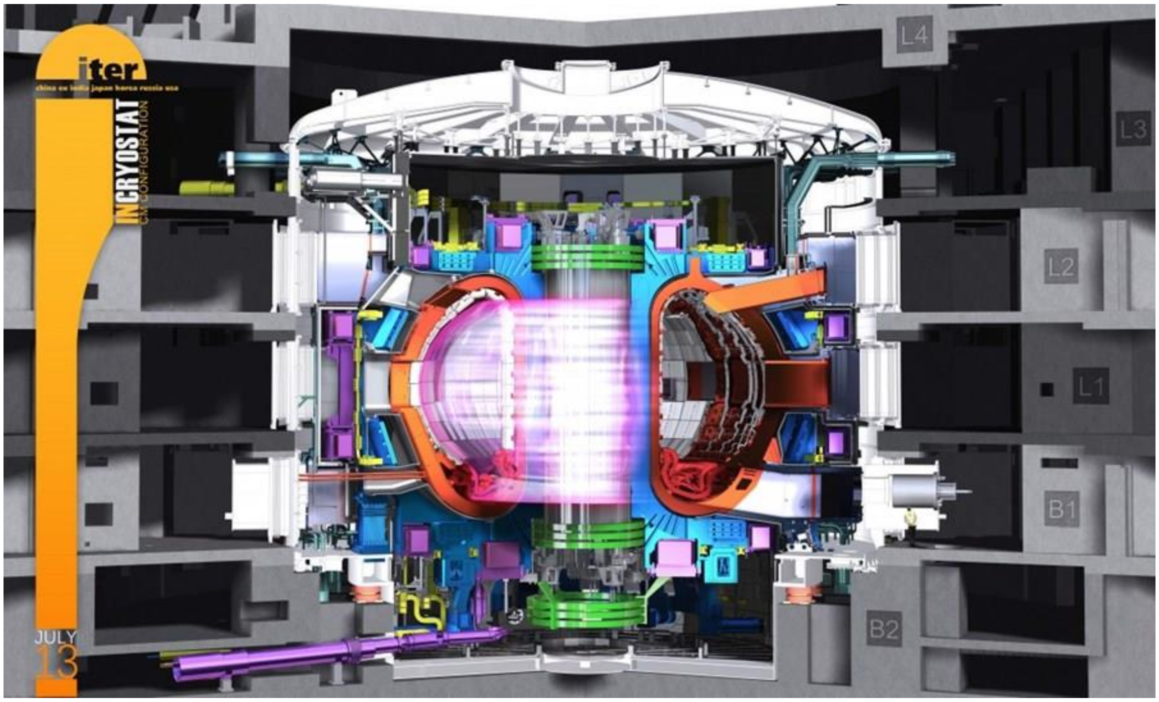
[1] https://www.iter.org/mach/Tokamak

confine the hot plasma away from the vessel walls. The term "tokamak" comes to us from a Russian acronym that stands for "toroidal chamber with magnetic coils" (тороидальная камера с магнитными катушками). Russia developed the first tokamak in the late 1960s.

To start the process, air and impurities are evacuated from the vacuum chamber. Next, the magnet systems that will help to confine and control the plasma are activated and the gaseous fuel is introduced. As a powerful electrical current is run through the vessel, the gas breaks down electrically, becomes ionized (electrons are stripped from the nuclei) and forms a plasma.

As the plasma particles become energized and collide they also begin to heat up. Auxiliary heating methods help to bring the plasma to fusion temperatures (between 150 and 300 million °C). Particles "energized" to such a degree can overcome their natural electromagnetic repulsion to fuse, releasing energy.

The diagram below is from the ITER website (reference 1)



The primary components in this design are:

White, Cryostat: The container in which a vacuum is maintained. This is the largest stainless steel vacuum chamber in the world – over 3,800 tonnes and 16,000 cubic meters.

Dark Orange, Plasma Chamber: 8,000 tonnes and 840 cubic meters.

Blue, Magnets: The magnet temperature is 4 Kelvins (4°C above absolute zero), and are made from 100,000 km of Niobium-Tin superconducting wire.

Purple, Blanket: Actively cooled thermal blanket (see subsection 4.1)

3. NIF

As I mentioned in the intro, NIF is in Livermore where I have lived most of my life. So I will start the description of NIF with a story from my past.

3.1. Nova

It was the late 1970s, and I was working as the facilities engineer for the GE Vallecitos Nuclear Center and lived in Livermore, not far from Lawrence Livermore National Labs (LLNL). In Livermore LLNL was commonly called the “Rad Lab” (from its progenitor, the University of California Radiation Lab). At that time my brother-in-law was a laser physicist at LLNL and was working on advanced laser experiments. One of these was Nova, an inertial confinement fusion (ICF) experiment, and a smaller version of NIF (more on this below). My brother-in-law invited me for a personal tour of Nova, which I quickly accepted.

In Nova a (then) huge bank of ten laser beamlines (each 600 ft. long) amplified a short pulse of light (2 to 4 nanoseconds) until it had about 100 kilojoules (about 28 watt-hours) of energy. Then the beam-line pulses were redirected by mirrors to symmetrically impact a small spherical target about the size of a BB. The surface of the target vaporized, but the vapor was confined by the incoming photons’ inertia, heated to a plasma state and compressed until the atoms in the target fused.[2]

However, there were issues with this design caused by the inability to match the output pulse of each beamline. This caused the compression of the target to be asymmetrical, and greatly reduced the high-energy neutrons emitted by each “shot”. Neutrons are important.

3.2. Thermonuclear Evolution & Dr. Teller

In order to explain the last sentence, I need to travel back a couple of decades more, to the last days of WWII. Many are familiar with the Manhattan Project, and the development of the atomic bomb, but fewer know about a project that (mostly) happened immediately after the War: the development of the first thermonuclear bomb / warhead. This was not a trivial development, and it required a major breakthrough: the Teller–Ulam design. Go through the link below if you would like to read the whole story:

https://www.atomicheritage.org/history/hydrogen-bomb-1950

In 1952 Teller left Los Alamos and joined the newly established Livermore branch of the University of California Radiation Laboratory, which had been created largely through his urging. After the detonation of Ivy Mike, the first thermonuclear weapon to utilize the Teller–Ulam configuration, on November 1, 1952, Teller became known in the press as the "father of the hydrogen bomb." Teller himself refrained from attending the test—he claimed not to feel welcome at the Pacific Proving Grounds—and instead saw its results on a seismograph in the basement of a hall in Berkeley...[3]

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[2] Wikiperdia Article on Nova (laser), https://en.wikipedia.org/wiki/Nova_(laser)

[3] Wikipedia Article on Edward Teller, https://en.wikipedia.org/wiki/Edward_Teller

Teller was Director of the Lawrence Livermore National Laboratory, which he helped to found with Ernest O. Lawrence, from 1958 to 1960, and after that he continued as an Associate Director (see photo and caption below)

LLNL was cofounded by Ernest O. Lawrence (left) and Edward Teller, the Laboratory began operations on Sept. 2, 1952, with Herbert York (right) serving as the first director.

Immediately after WWII and through the 1950s the only way to test a nuclear weapon and its components were to build a prototype and detonate it above ground. But there was increasing pressure to stop atmospheric testing. *On August 5, 1963, representatives of the United States, Soviet Union and Great Britain signed the Limited Nuclear Test Ban Treaty, which prohibited the testing of nuclear weapons in outer space, underwater or in the atmosphere.*[4]

So testing went underground (literally). On September 19, 1957, the Laboratory (LLNL) detonated the first contained underground nuclear explosion. Rainier (project name) was fired beneath a high mesa at the northwest corner of the Nevada Test Site (NTS), which later became known as Rainier Mesa.[5]

The above test was a prelude to the period between the banning of atmospheric tests (1963) and the banning of all tests, including underground, in 1992. During this period LLNL participated in underground testing at NTS. After that date underground nuclear tests were no longer required due to improved computer modeling, and other programs to analyze the operation of nuclear weapons.

3.3. Stewardship

“Make no mistake: As long as these [nuclear] weapons exist, the United States will maintain a safe, secure, and effective arsenal to deter any adversary, and guarantee that defense to our allies.”[6]

—Barack Obama, 2009

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[4] History, “Nuclear Test-Ban Treaty”, updated on Aug 21, 2018, https://www.history.com/topics/cold-war/nuclear-test-ban-treaty

[5] LLNL, “Lawrence Livermore National Laboratory, 1952-2017”, https://www.llnl.gov/sites/www/files/llnl_65th_anniversary_book.pdf

[6] LLNL. Weapons and Complex Integration, “Stockpile Stewardship Program”, https://wci.llnl.gov/science/stockpile-stewardship-program

Both Nova and NIF played / play an important part in this effort.

Since the Cold War, United States policy has pivoted from production to maintenance of the nation's nuclear stockpile. In 1992, nuclear weapon development ceased with a national moratorium on nuclear testing. The end of the nuclear arms race dramatically affected the nation's three weapon laboratories—Livermore, Los Alamos, and Sandia—but their central missions remain focused on national security science and technology. Although the U.S. stockpile of weapons is smaller than it used to be, nuclear deterrence remains an integral part of national security policy. In 1995, the Stockpile Stewardship Program was born.

The Stockpile Stewardship Program is an ambitious effort to improve the science and technology for assessing an aging nuclear weapons stockpile without relying on nuclear testing. For this program to succeed, all aspects of weapons must be understood in sufficient detail so experts can evaluate weapon performance with confidence and make informed decisions about refurbishing, remanufacturing, or replacing weapons as needs arise.

Each year, together with Los Alamos and Sandia national laboratories, we are required to provide an assessment of the stockpile's safety, security, and reliability to the National Nuclear Security Administration (NNSA) and the President.

The major initiatives in this effort include:

Weapon Life extension. *Our stewardship efforts face challenges with aging materials, older designs, and obsolescent parts for weapons with a 20-year service life…*

Predictive modeling. *In the absence of experimental testing, we develop three-dimensional simulations and other computational tools. This advanced computational power enables scientists to integrate disparate information into an assessment of weapon system performance, margins, and uncertainties.*

Plutonium science. *Over time, changes in plutonium's chemical structure (or phase) could compromise weapons performance. Our team performs ongoing experiments to understand the element's aging process and dynamic behavior.*

High-explosive science. *A nuclear weapon's detonation process cannot occur without a precision-designed high explosive creating the main charge. Working at LLNL's High Explosives Applications Facility (HEAF), our chemists have developed "insensitive" high explosives that are much less likely to accidentally detonate than conventional explosives used in most weapons.*

High-energy-density science. *Measuring strength and other dynamic properties of weapons materials requires experimentation with thermonuclear processes to validate theoretical models. We accomplish this in the post-nuclear-test era with the 192-beam laser system at the National Ignition Facility (NIF), producing extreme environments to improve understanding of weapon physics.*

3.4. Nova to NIF

Nova's partial success, combined with other experimental numbers, prompted Department of Energy to request a custom military ICF facility they called the "Laboratory Microfusion Facility" (LMF) that could achieve fusion yield between 100 and 1000 MJ (megajoules, each MJ is about 0.28 kWh).[2]

In July 1992 LLNL responded to these suggestions with the Nova Upgrade, which would reuse the majority of the existing Nova facility, along with the adjacent Shiva facility…

Note from Author: Shiva was the first laser inertial confinement experiment and operated from 1978 to 1981.

For reasons that are not well recorded in the historical record, later in 1992 LLNL updated their Nova Upgrade proposal and stated that the existing Nova/Shiva buildings would no longer be able to contain the new system, and that a new building about three times as large would be needed. From then on the plans evolved into the current National Ignition Facility.

From the above you can see that Nova and NIF had/have three jobs. The primary job is to better understand the complexities of inertial confinement fusion (ICF). The second most important job is NIF's role in Stockpile Stewardship Program as described in the prior subsection, and finally the least important role is moving NIF's design to one that is appropriate (financially and otherwise) for a commercial power plant. Much of this last role is done outside of NIF, but occasional experiments in NIF keep it moving along.

4. Power Plant Development

Several groups of major development tasks must be successfully executed in order to create a design that is ready for the detailed engineering of a Fusion Power Plant.

LIFE, short for Laser Inertial Fusion Energy, was a fusion energy effort run at Lawrence Livermore National Laboratory between 2008 and 2013. LIFE aimed to develop the technologies necessary to convert the laser-driven inertial confinement fusion concept being developed in the National Ignition Facility (NIF) into a practical commercial power plant, a concept known generally as inertial fusion energy (IFE). LIFE used the same basic concepts as NIF, but aimed to lower costs using mass-produced fuel elements, simplified maintenance, and diode lasers with higher electrical efficiency.[7]

The items in the following subsections were identified and researched during the LIFE Project.

4.1. Neutron Embrittlement

One of the cost concerns for Magnetic Confinement Fusion (MCF) designs like ITER is that the reactor materials are subject to the intense neutron flux created by the fusion reactions. When high-energy neutrons impact materials they displace the atoms in the structure leading to a problem known as neutron embrittlement that degrades the structural integrity of the material. This is a problem for fission reactors as well, but the neutron flux and energy in a tokamak is greater than most fission designs. In most MCF designs, the reactor is constructed in layers, with a toroidal inner vacuum chamber, or "first wall", then the blanket, and finally the superconducting magnets that produce the field that confines the plasma. Neutrons stopping in the blanket are desirable, but those that stop in the first wall or magnets degrade them…

From reference 1: *The ITER blanket, which covers a surface of 600 m², is one of the most critical and technically challenging components in ITER: … it directly faces the hot*

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[7] Wikipedia Article on Laser Inertial Fusion Energy, https://en.wikipedia.org/wiki/Laser_Inertial_Fusion_Energy

plasma. Due to its unique physical properties (low plasma contamination, low fuel retention), beryllium has been chosen as the element to cover the first wall. The rest of the blanket modules will be made of high-strength copper and stainless steel.

Comment from author: The cost of Beryllium per gram is $23[8]

ITER will be the first fusion device to operate with an actively cooled blanket. The cooling water—injected at 580 psi and 158 °F—is designed to remove up to 736 MW of thermal power.

From Reference 7*: As a natural side-effect of the size of the fuel elements and their resulting explosions, inertial confinement fusion (ICF) designs use a very large reaction chamber many meters across. This lowers the neutron flux on any particular part of the chamber wall through the inverse-square law. Additionally, there are no magnets or other complex systems near or inside the reactor, and the laser is isolated on the far side of long optical paths. The far side of the chamber is empty, allowing the blanket to be placed there and easily maintained. Although the reaction chamber walls and final optics would eventually embrittle and require replacement, the chamber is essentially a large steel ball of relatively simple multi-piece construction that could be replaced without too much effort. The reaction chamber is, on the whole, dramatically simpler than those in magnetic fusion concepts, and the LIFE designs proposed building several and quickly moving them in and out of production…*

4.2. Inefficient Laser Pumping

NIF's laser uses a system of large flashtubes (like those in a photography flashlamp) to optically pump a large number of glass plates. Once the plates are flashed and have settled into a population inversion, a small signal from a separate laser is fed into the optical lines, stimulating the emission in the plates. The plates then dump their stored energy into the growing beam, amplifying it billions of times.

The process is extremely inefficient in energy terms; NIF feeds the flashtubes over 400 MJ of energy which produces 1.8 MJ of ultraviolet (UV) light. Due to limitations of the target chamber, NIF is only able to handle fusion outputs up to about 50 MJ, although shots would generally be about half of that. Accounting for losses in generation, perhaps 20 MJ of electrical energy might be extracted at the maximum, accounting for less than 1⁄20 of the input energy…

LLNL had begun exploring different solutions to the laser problem while the system was first being described. In 1996 they built a small testbed system known as the Mercury laser that replaced the flashtubes with laser diodes.

One advantage of this design was that the diodes created light around the same frequency as the laser glass' output, as compared to the white light flashtubes where most of the energy in the flash was wasted as it was not near the active frequency of the laser glass. This change increased the energy efficiency to about 10%, a dramatic improvement.]

For any given amount of light energy created, the diode lasers give off about 1⁄3 as much heat as a flashtube. Less heat, combined with active cooling in the form of helium blown between the diodes and the laser glass layers, eliminated the warming of the

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[8] https://allaboutberyllium.weebly.com/facts-about-beryllium.html

glass and allows Mercury to run continually. In 2008, Mercury was able to fire 10 times a second at 50 joules per shot for hours at a time.

4.3. Large Laser Beamlines

LIFE was essentially a combination of the Mercury concepts and new physical arrangements to greatly reduce the volume of the NIF while making it much easier to build and maintain. Whereas an NIF beamline for one of its 192 lasers is over 330 ft. long, LIFE was based on a design about 34 ft. long that contained everything from the power supplies to frequency conversion optics. Each module was completely independent… allowing the units to be individually removed and replaced while the system as a whole continued operation.

Each driver cell in the LIFE baseline design contained two of the high-density diode arrays arranged on either side of a large slab of laser glass. The arrays were provided cooling via hook-up pipes at either end of the module…

The small size and independence of the laser modules allowed the huge NIF building to be dispensed with. Instead, the modules were arranged in groups surrounding the target chamber in a compact arrangement…

The ultimate goal was to produce a system that could be shipped in a conventional semi-trailer truck to the power plant, providing laser energy with 18% end-to-end efficiency, 15 times that of the NIF system… The consensus was that this "beam-in-a-box" system could be built for 3 cents per Watt of laser output, and that would reduce to 0.7 cents/W in sustained production…

4.4. Extremely Expensive Targets

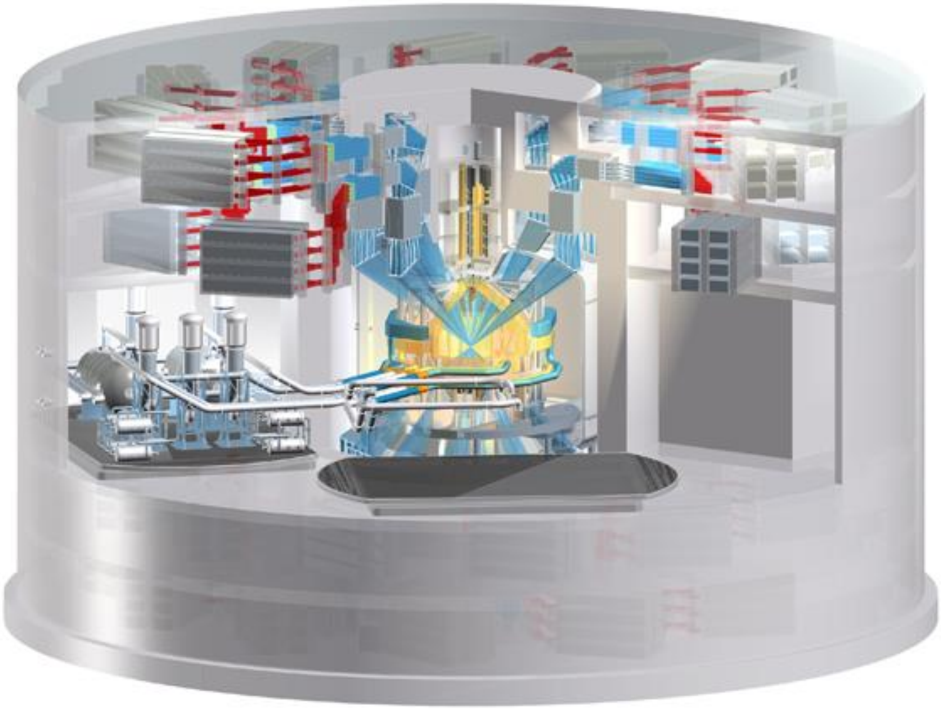
*Each target consists of a small open-ended metal cylinder (**hohlraum**) with transparent double-pane windows sealing each end. In order to efficiently convert the driver laser's light to the x-rays that drive the compression, the cylinder has to be coated in gold or other heavy metals. Inside… is a hollow plastic sphere containing the fuel. In order to provide symmetrical implosion, the metal cylinder and plastic sphere have extremely high machining tolerances. The fuel, normally a gas at room temperature, is deposited inside the sphere and then cryogenically frozen until it sticks to the inside of the sphere. It is then smoothed by slowly warming it with an infrared laser to form a 100 µm smooth layer on the inside of the pellet. Each target costs tens of thousands of dollars.*

To address this concern, a considerable amount of LIFE's effort was put into the development of simplified target designs and automated construction that would lower their cost. Working with General Atomics, the LIFE team developed a concept using on-site fuel factories that would mass-produce pellets at a rate of about a million a day. It was expected that this would reduce their price to about 25 cents per target, although other references suggest the target price was closer to 50 cents, and LLNL's own estimates range from 20 to 30 cents.

4.5. Overall Design

By 2012, the baseline design of the pure fusion concept, known as the Market Entry Plant (MEP), had stabilized. This was a self-contained design with the entire fusion section packaged into a cylindrical concrete building not unlike a fission reactor confinement building, although larger at 330 ft. diameter. The central building was flanked by smaller rectangular buildings on either side, one containing the turbines and *power handling systems, the other the tritium plant. A third building, either attached to the plant or behind it depending on the diagram, was used for maintenance.*

Inside the central fusion building (pictured below), the beam-in-a-box lasers were arranged in two rings, one above and one below the target chamber (note that the lower ring can only be seen as a ghost). A total of 384 lasers would provide 2.2 MJ of UV light... A light-gas gun was used to fire 15 targets a second into the target chamber. With each shot, the temperature of the target chamber's inner wall is raised from 600 °C (1,112 °F) to 800 °C (1,470 °F).



The target chamber is a two-wall structure filled with liquid lithium or a lithium alloy between the walls. The lithium captures neutrons from the reactions to breed tritium, and also acts as the primary coolant loop. The chamber is filled with xenon gas that would slow the ions from the reaction as well as protect the inner wall, or first wall, from the massive x-ray flux. Because the chamber is not highly pressurized, like a fission core, it does not have to be built as a single sphere. Instead, the LIFE chamber is built from eight identical sections that include built-in connections to the cooling loop. They are shipped to the plant and bolted together on two supports, and then surrounded by a tube-based space frame.

Comment from the author: Note that liquid lithium (or a lithium alloy) is used as the primary coolant / heat transfer media. Also note that the lithium breeds tritium. The most efficient fission reaction uses deuterium and tritium as fuel, and tritium is exceptionally rare. However when fast neutrons impact lithium atoms, in addition to transferring their kinetic energy to the lithium (and heating it), they breed tritium, which can be chemically separated from the lithium. Also lithium is an alkali metal (like sodium and potassium) and has excellent heat transfer characteristics. Its melting point is about 350°F and its boiling point is over 2,400°F.

To deal with embrittlement, the entire target chamber was designed to be easily rolled out of the center of the building on rails to the maintenance building where it could be rebuilt. The chamber was expected to last four years, and be replaced in one month. The optical system is decoupled from the chamber, which isolates it from vibrations during operation and means that the beamlines themselves do not have to be realigned after chamber replacement.

The plant had a peak generation capability, or nameplate capacity, of about 400 MWe, with design features to allow expansion to as much as 1000 MWe.

4.6. Economics

The levelized cost of electricity (LCoE) can be calculated by dividing the total cost to build and operate a power-generating system over its lifetime by the total amount of electricity shipped to the grid during that period…

…Over a year, a second generation LIFE would produce 365 days x 24 hours x 0.9 capacity factor x 1,000,000 kW nameplate rating = 8 billion kWh. The average rate for wholesale electricity in the US as of 2015 is around 5 cents/kWh, so this power has a commercial value of about $212 million…

CAPEX for the plant is estimated to $6.4 billion, so financing the plant over a 20-year period adds another $5 billion assuming the 6.5% unsecured rate. LLNL calculated the LCOE of Gen 2 LIFE at 9.1 cents using the discounted cash flow methodology described in the 2009 MIT report "the Future of Nuclear Energy". Using either value, LIFE would be unable to compete with modern renewable energy sources, which are well below 5 cents/kWh as of 2018.

LLNL projected that further development after widespread commercial deployment might lead to further technology improvements and cost reductions, and proposed a third generation LIFE design of about $6.3 billion CAPEX and 1.6 GW nameplate for a price per watt of $4.2/W. This leads to a projected LCOE of 5.5 cents/kWh, which is competitive with offshore wind as of 2018, but unlikely to be so in 2040 when LIFE Gen 3 designs would start construction. LIFE plants would be wholesale sellers, competing against a baseload rate of about 5.3 cents/kWh as of 2015.

The steam turbine section of a power plant, the turbine hall, generally costs about $1/W, and the electrical equipment to feed that power to the grid is about another $1/W. To reach the projected total CAPEX quoted in LIFE documents, this implies that the entire nuclear island has to cost around $4/W for LIFE Gen 2, and just over $2/W for LIFE Gen 3. Modern nuclear plants, benefiting from decades of commercial experience and continuous design work, cost just under $8/W, with approximately half of that in the nuclear island. LLNL's estimates require LIFE Gen 3 to be built in 2040 for about half the cost of a fission plant today.

4.7. Update – Burning Plasma

From this source,[9] *NIF researchers believe they are close to an important intermediate milestone known as "burning plasma": a fusion burn sustained by the heat of the reaction itself rather than the input of laser energy.*

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[9] Daniel Clery, Science, "Laser fusion reactor approaches 'burning plasma' milestone", Nov. 23, 2020, https://www.sciencemag.org/news/2020/11/laser-fusion-reactor-approaches-burning-plasma-milestone

Self-heating is key to burning up all the fuel and getting runaway energy gain. Once NIF reaches the threshold, simulations suggest it will have an easier path to ignition, says Mark Herrmann, who oversees Livermore's fusion program. "We're pushing as hard as we can," he says. "You can feel the acceleration in our understanding." Outsiders are impressed, too. "You kind of feel there's steady progress and less guesswork," says Steven Rose, co-director of the Centre for Inertial Fusion Studies at Imperial College London. "They're moving away from designs traditionally held and trying new things."

NIF may not have the luxury of time, however. The proportion of NIF shots devoted to the ignition effort has been cut from a high of nearly 60% in 2012 to less than 30% today to reserve more shots for stockpile stewardship—experiments that simulate nuclear detonations to help verify the reliability of warheads…

In the current campaign, begun in 2017, researchers are boosting temperatures by enlarging the hohlraum (see subsect. 4.4) and the capsule by up to 20%, increasing the x-ray energy the capsule can absorb. To up the pressure, they're extending the duration of the pulse and switching from plastic capsules to denser diamond ones to compress the fuel more efficiently.

NIF has repeatedly achieved yields approaching 60 kJ. But Herrmann says a recent shot, discussed at the American Physical Society's Division of Plasma Physics meeting earlier this month, has exceeded that. Repeat shots are planned to gauge how close they got to a burning plasma, which is predicted to occur around 100 kJ. "It's pretty exciting," he says.

Even at maximum compression, the NIF researchers believe only the very center of the fuel is hot enough to fuse. But in an encouraging finding, they see evidence that the hot spot is getting a heating boost from frenetically moving helium nuclei, or alpha particles, created by the fusion reactions. If NIF can pump in just a bit more energy, it should spark a wave that will race out from the hot spot, burning fuel as it goes.

Herrmann says the team still has a few more tricks to try out—each of which could drive temperatures and pressures to levels high enough to sustain burning plasma and ignition. They are testing different hohlraum shapes to better focus energy onto the capsule. They're experimenting with double-walled capsules that could trap and transfer x-ray energy more efficiently. And by soaking the fuel into a foam within the capsule, rather than freezing it as ice to the capsule walls, they hope to form a better central hot spot.

5. *Conclusion*

ITER is near a complete design that appears to be power plant ready. The problems are:

- It doesn't exist yet
- Eye-wateringly high price ($25 Billion)

NIF, is much less expensive than ITER, has its cost spread among multiple customers/ applications and has developed a path to practicality in LIFE.

As basic science, both of these experiments are important – the more we know about these processes (that are the edge of known science) the more we will be able to use them in the (distant) future. Perhaps even to build future power plants.