Future Directions For Inertial Fusion

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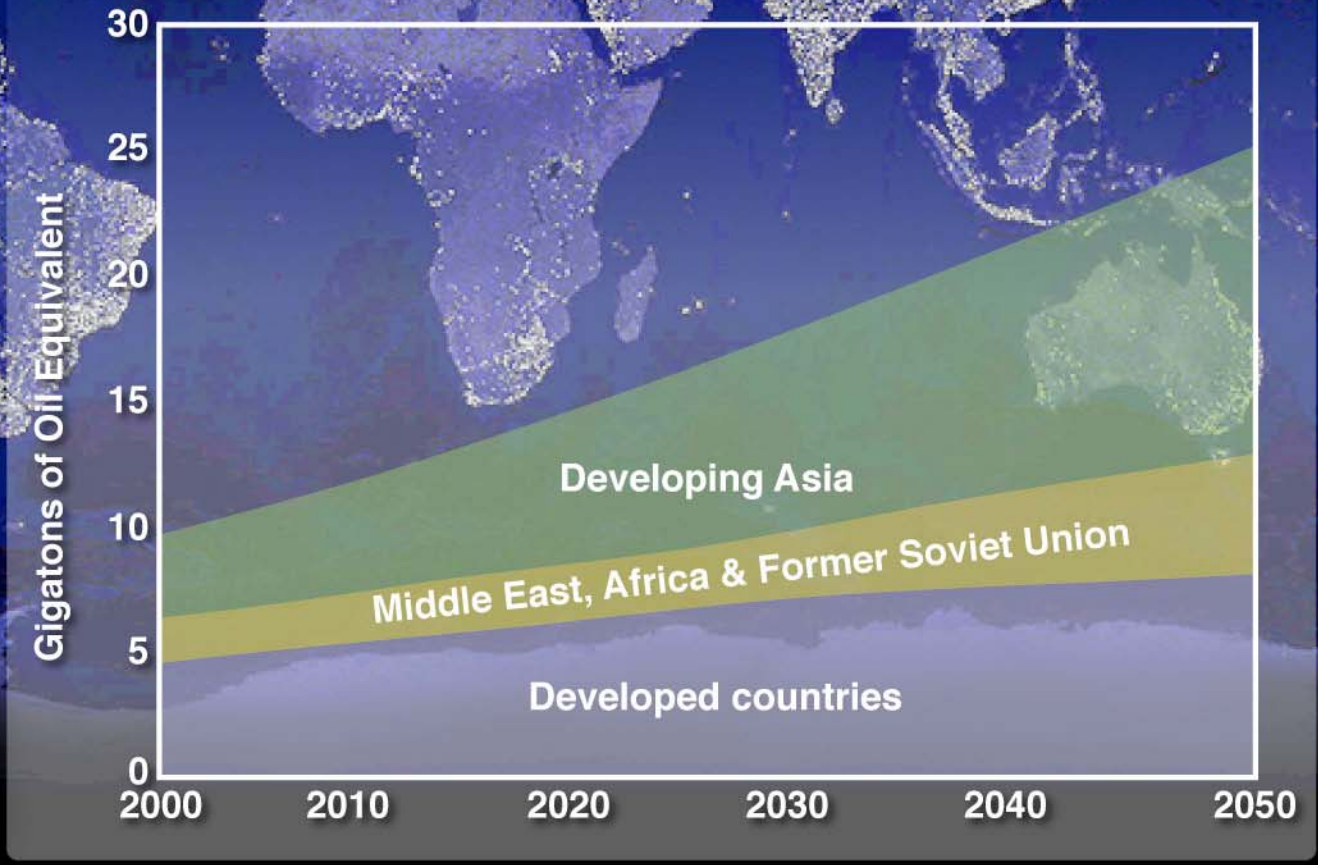
Clean energy: Humankind's challenge

Global Factors

- Population increase
- Developing countries
- Resource depletion
- Climate change

This challenge must be resolved and solved today...Not 50 years from now



Achieving ignition at the National Ignition Facility can be a defining moment for the world's energy future

We are developing "LIFE," a fusion/fission hybrid approach for power generation

A variety of drivers have been considered for IFE

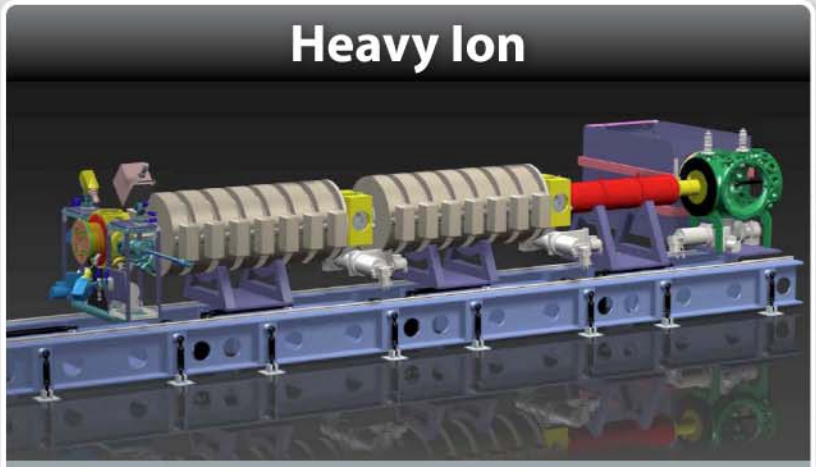
Solid State Lasers

LLNL

KrF Lasers

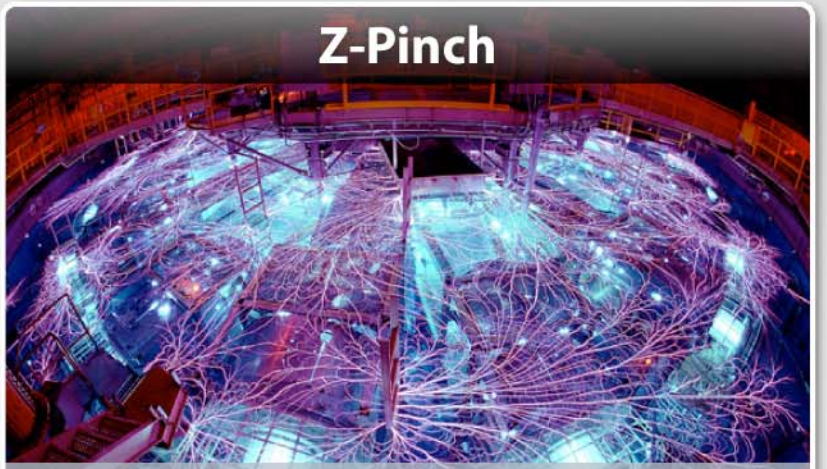
NRL

Heavy Ion



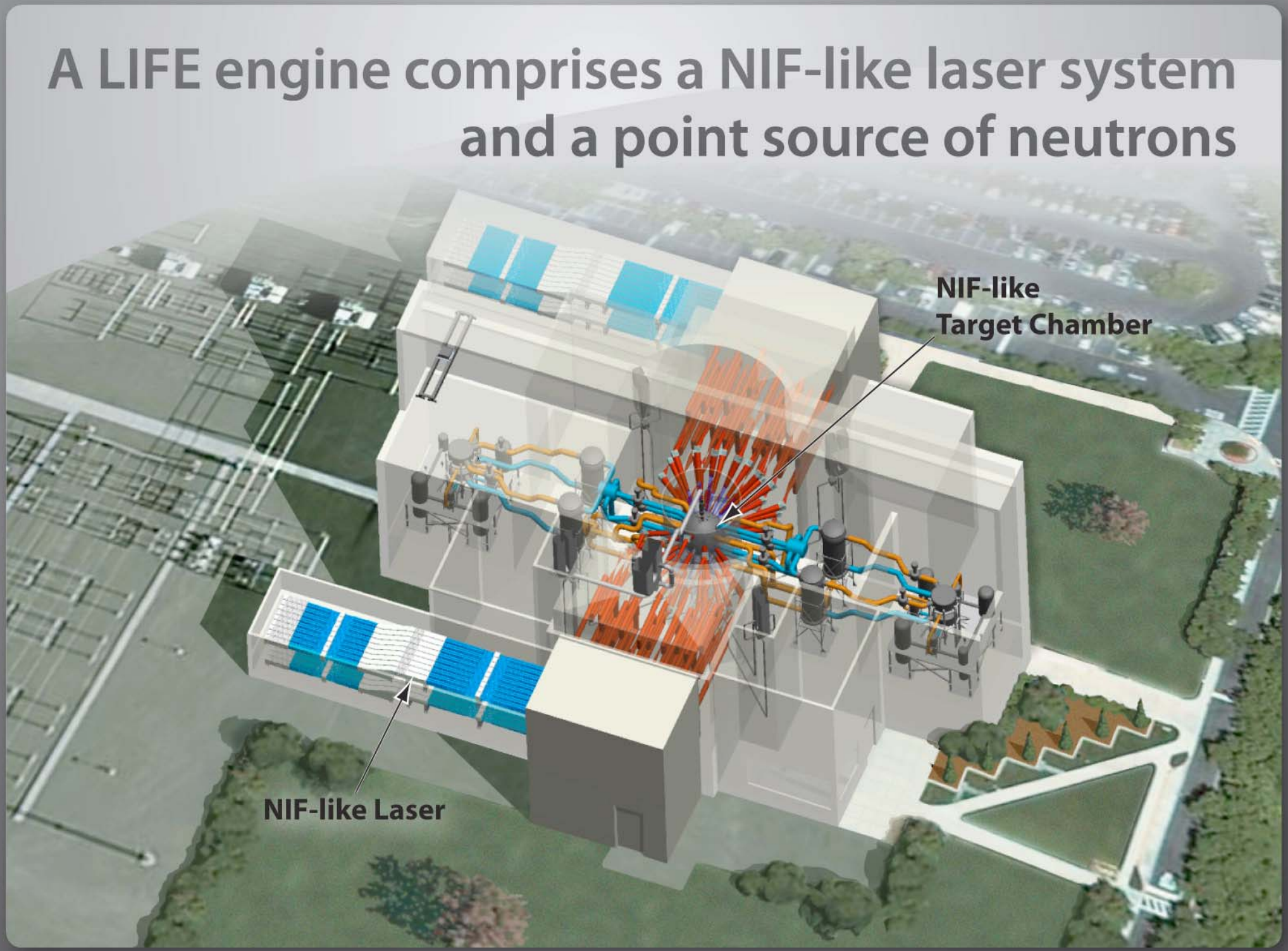
Virtual National Laboratory

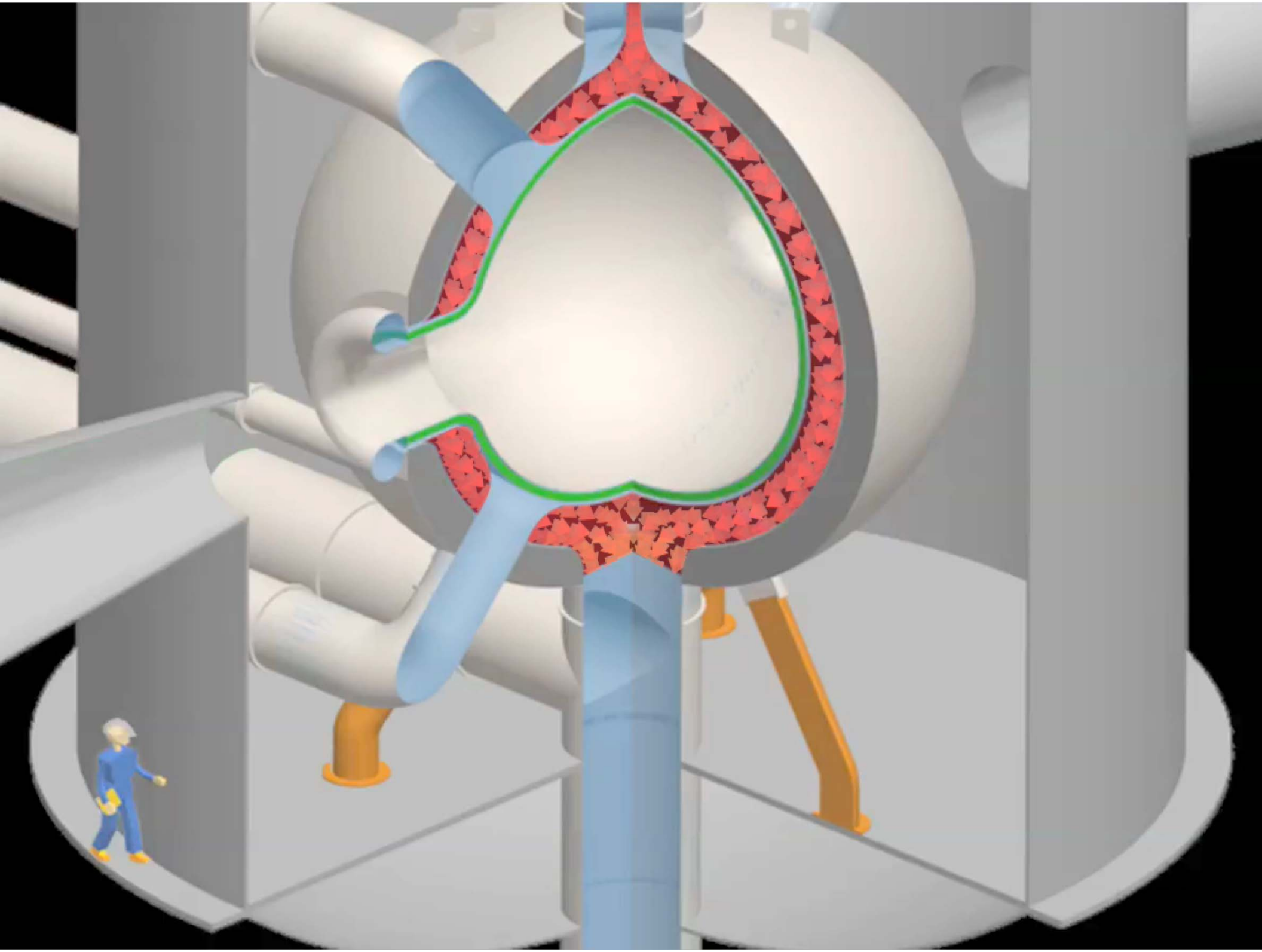
Z-Pinch

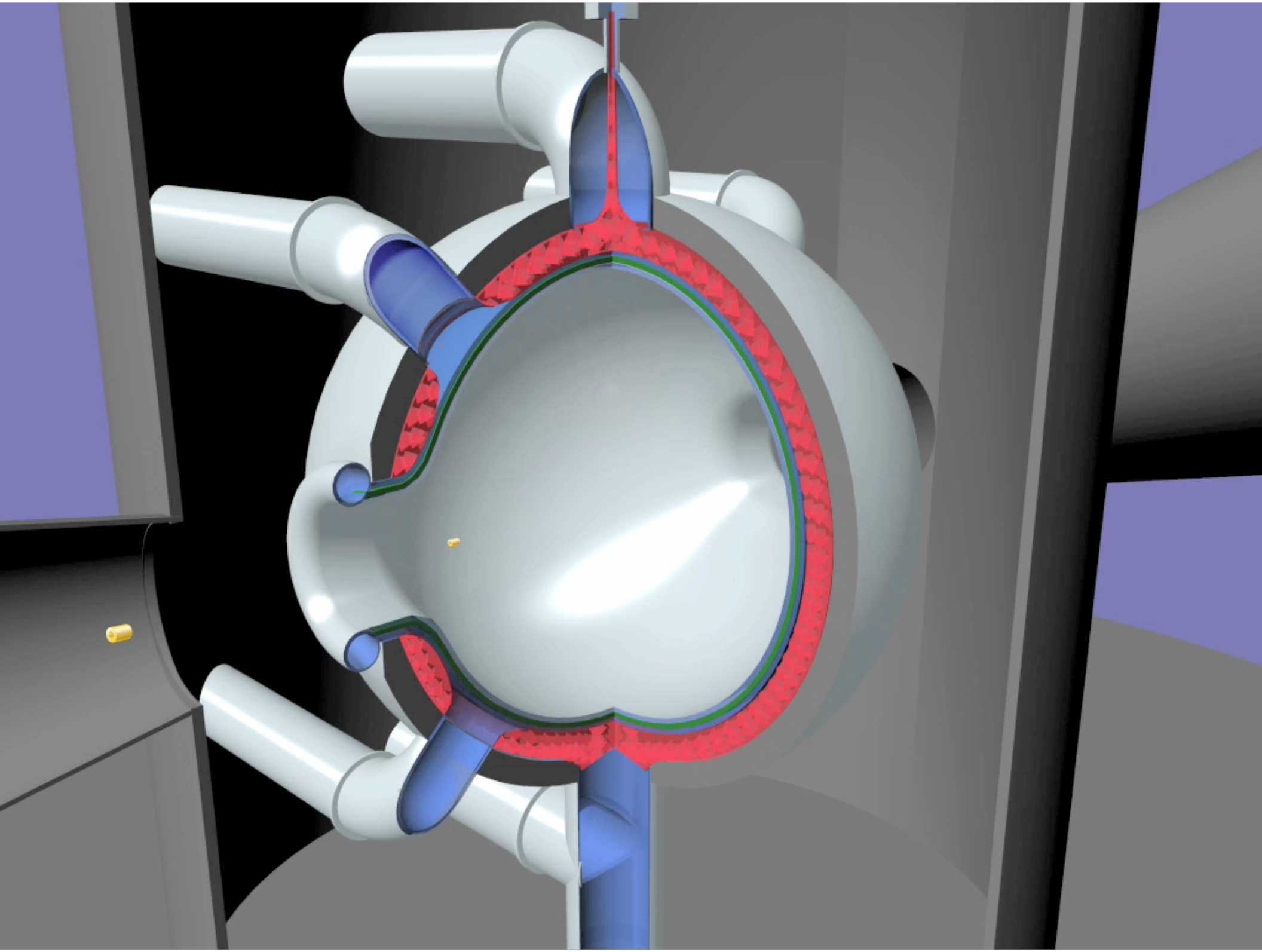


SNL

A LIFE engine comprises a NIF-like laser system and a point source of neutrons

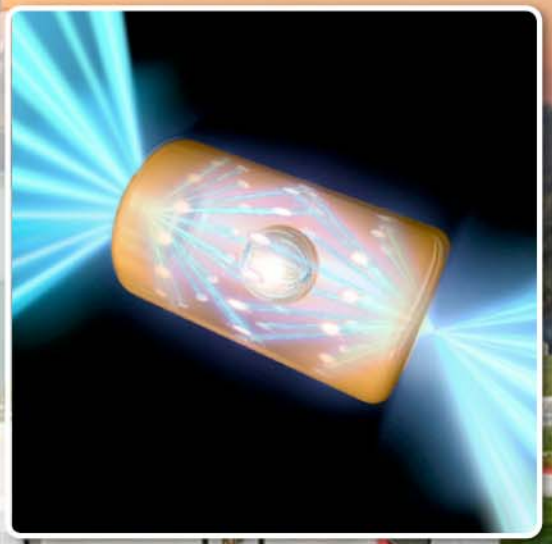






Inertial Fusion Energy

- High neutron yield
- No greenhouse gasses
- No radioactive waste



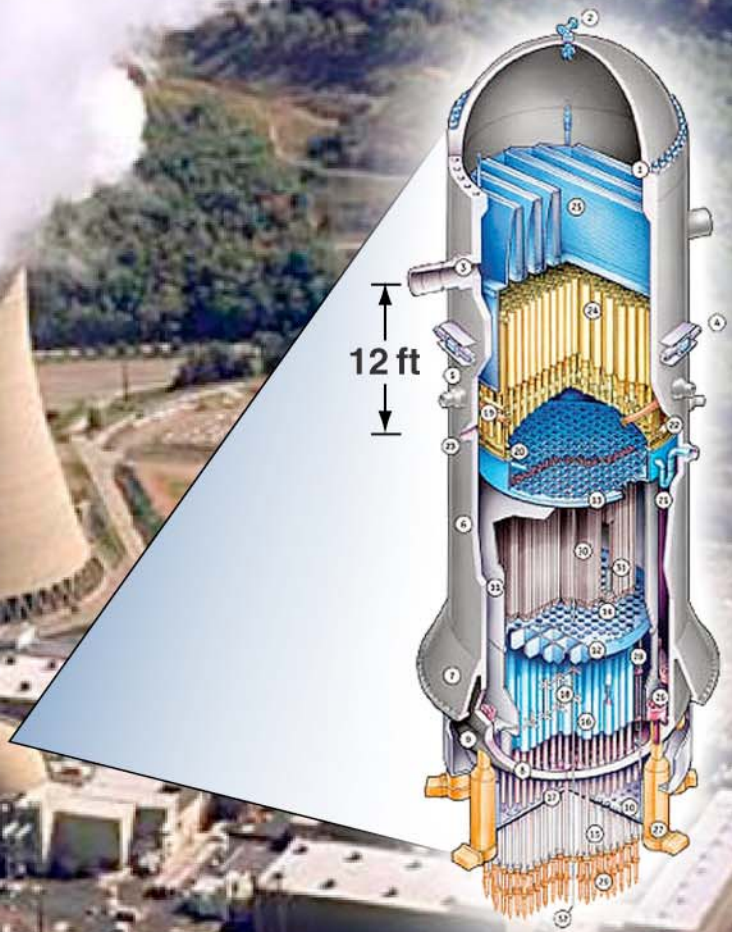
Pure fusion solutions are technologically and economically challenging

Nuclear energy could be used to provide clean energy

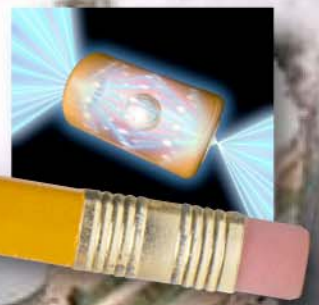
- Simple
- Compact
- Reliable
- No greenhouse gasses

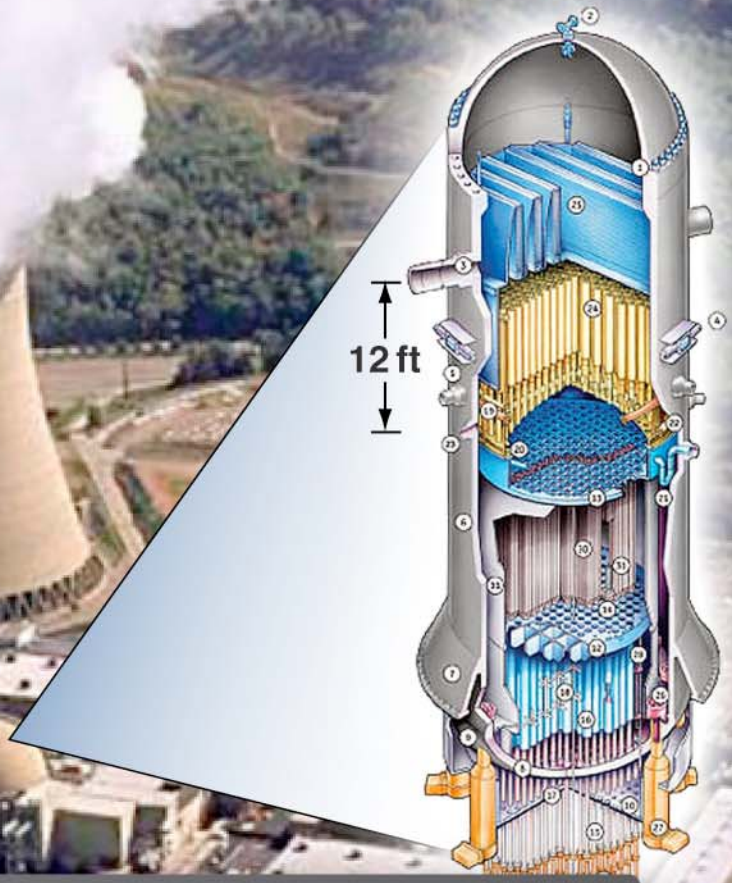
But…

- Requires enrichment
- Uses only 1/2% of energy of fuel (self-poisoning)
- Generates waste
- Critical assembly necessary



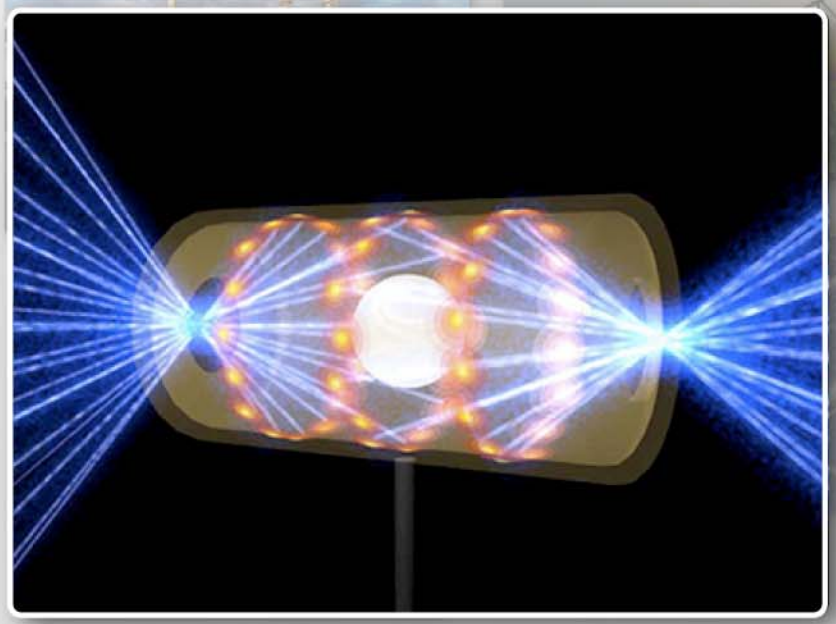
LIFE combines the best aspects of nuclear fusion and fission - neutrons and energy





Fusion/Fission hybrids: A marriage made in heaven

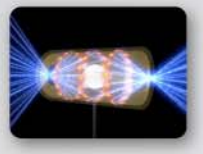
LIFE could be the answer!



The revolutionary should be pursued with the evolutionary*

*Robert Socolow - Commentary in *Nature* 452, 508–509 (2008)

LIFE energy and material flow



Fusion Driver Gain ≈ 30 – 60

2×10^{14} n/cm^2/s

Natural / Depleted U

Spent Nuclear Fuel

Weapons Pu

Gain ≈ 4-10

2000 – 4000 MW_{th}

Total Gain ≈ 120 – 600

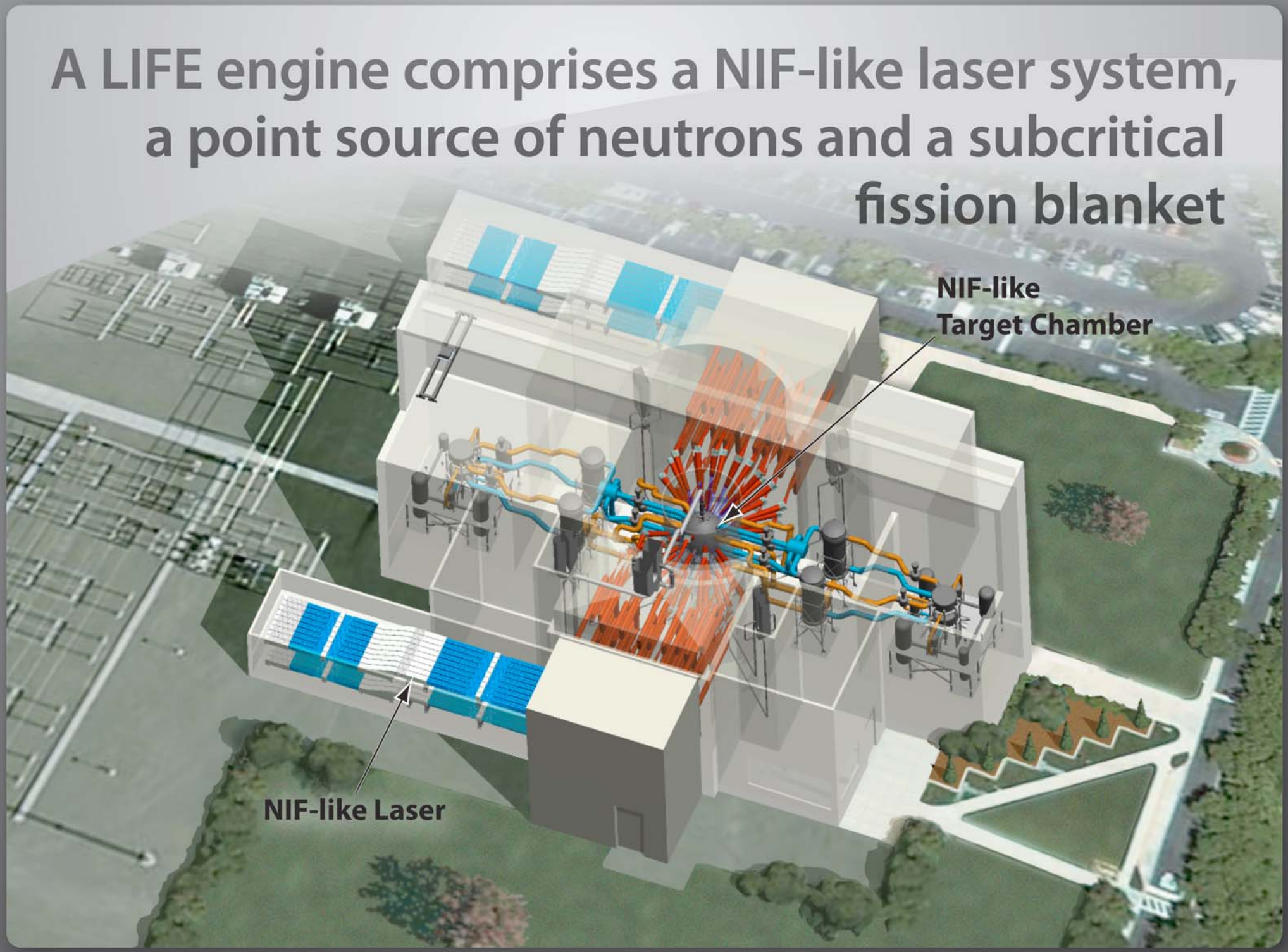
>99% Burn-up

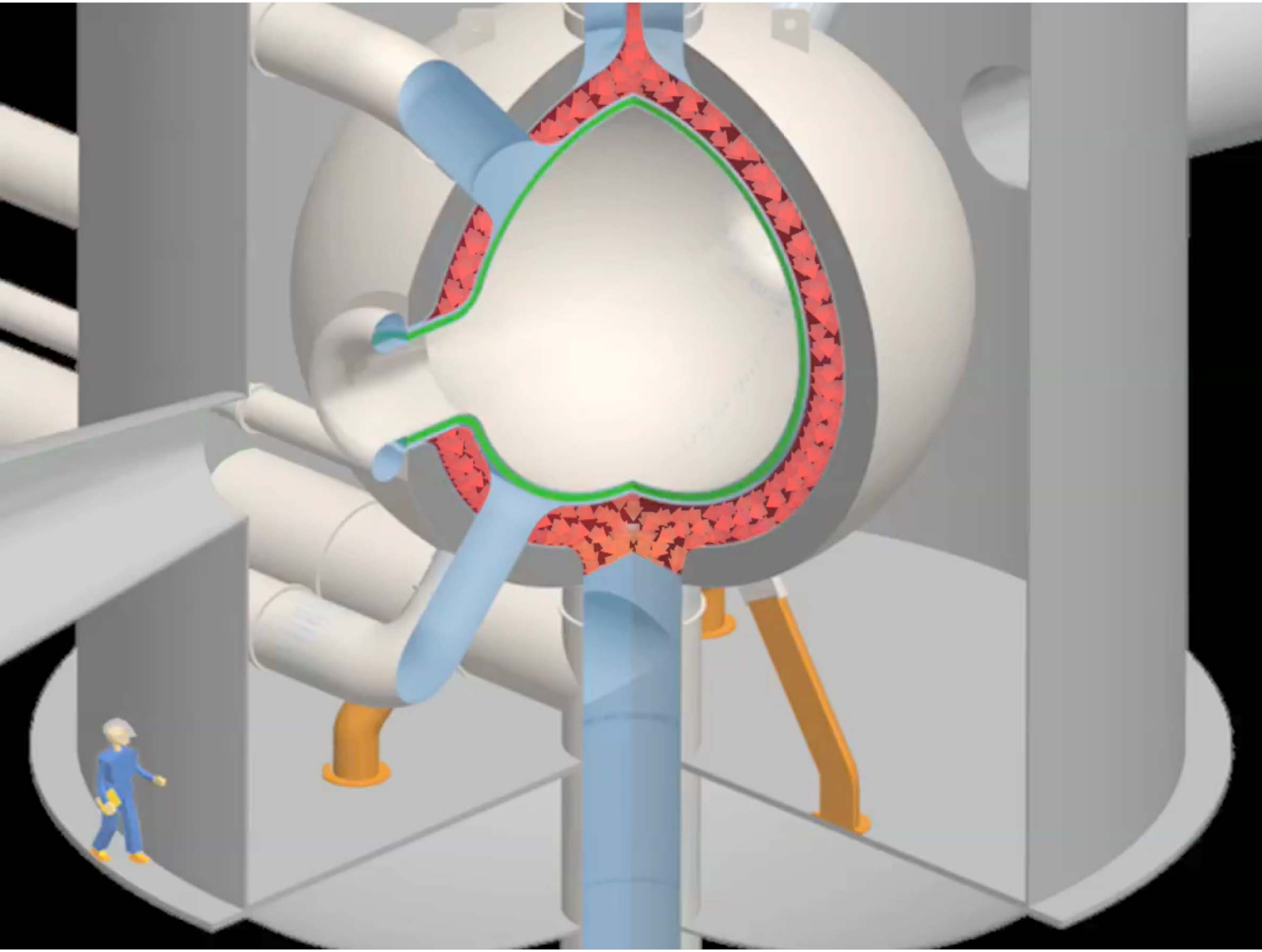
Fission Products

Waste Disposal

LIFE is once-through, "complete" burn-up closed fuel cycle

A LIFE engine comprises a NIF-like laser system, a point source of neutrons and a subcritical fission blanket

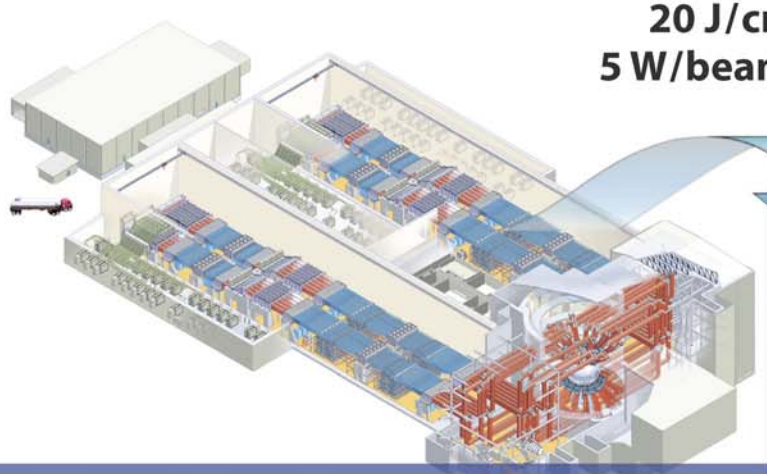




NIF is a precursor to LIFE

NIF (2 MJ)

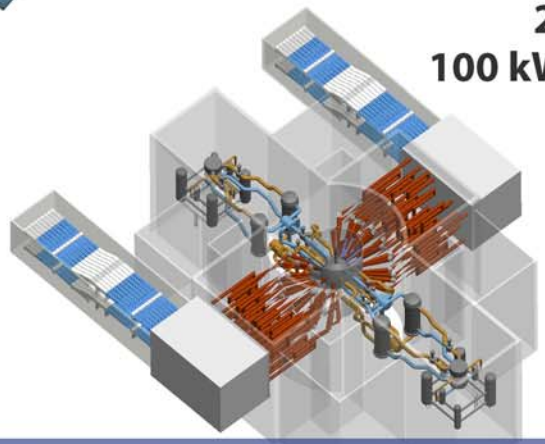
20 J/cm^2
5 W/beams



Repetition frequency 10^{-4} Hz
Electrical efficiency 1%

LIFE (17 MW)

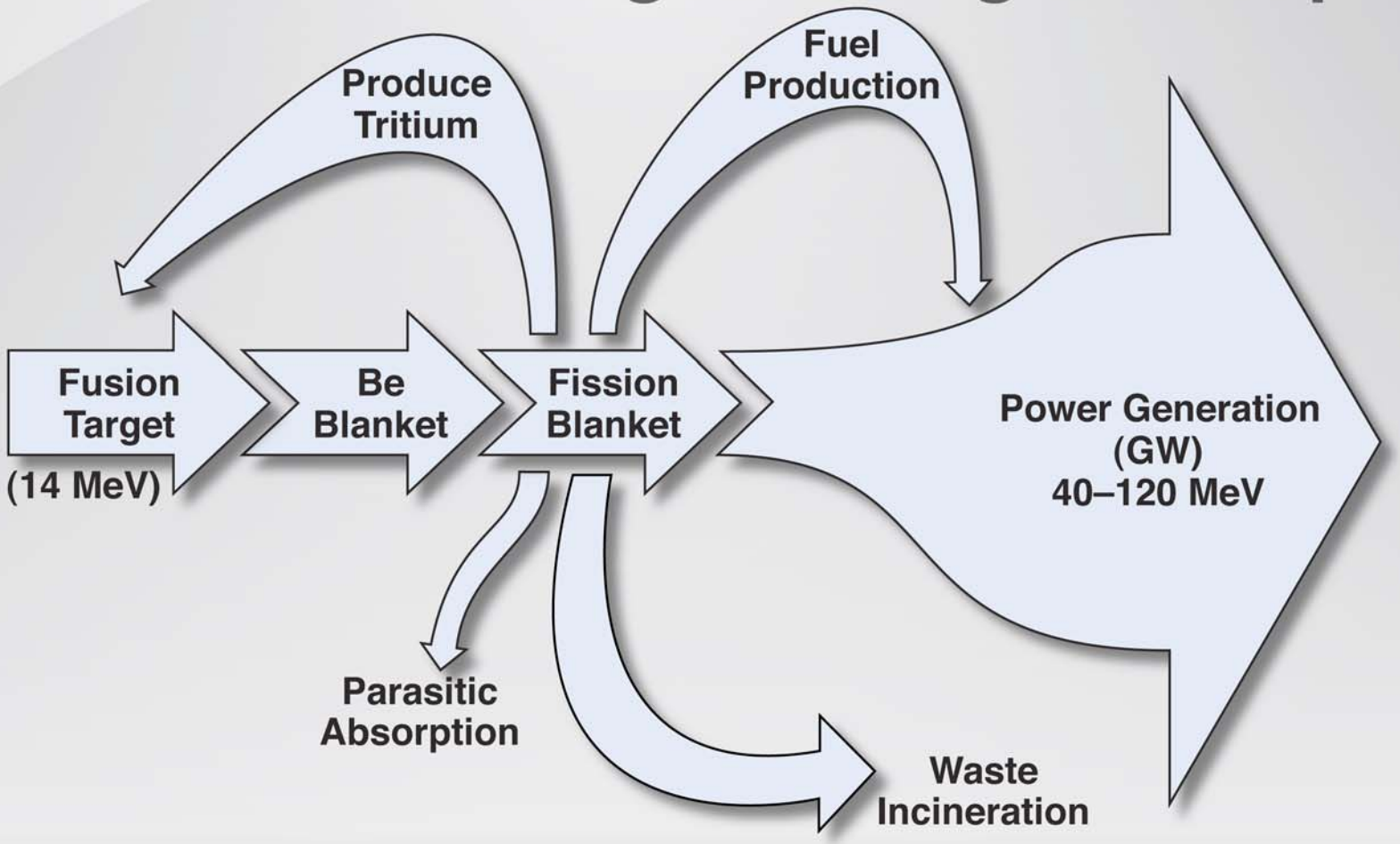
20 J/cm^2
100 kW/Beam



Repetition frequency 13 Hz
Electrical efficiency >10%

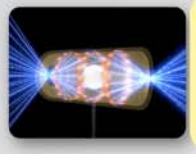
- Fluence is identical
- He cooling enables average power
- Diode pumping enables efficiency

A LIFE engine is a closed, self-contained system that breeds and burns its own fuel while generating GWs of power



In a LIFE engine, a neutron-rich inertial fusion point source drives an energy-rich fission blanket to generate energy, make its own fuel and incinerate waste

A LIFE engine is a once-through, closed, fuel cycle for DU



Fusion Neutron

500 MW

Neutron Multiplier

-20 MW

Fission Blanket

129 MW

Produce Tritium

171 MW

Fuel Production

Power Generation (GW)

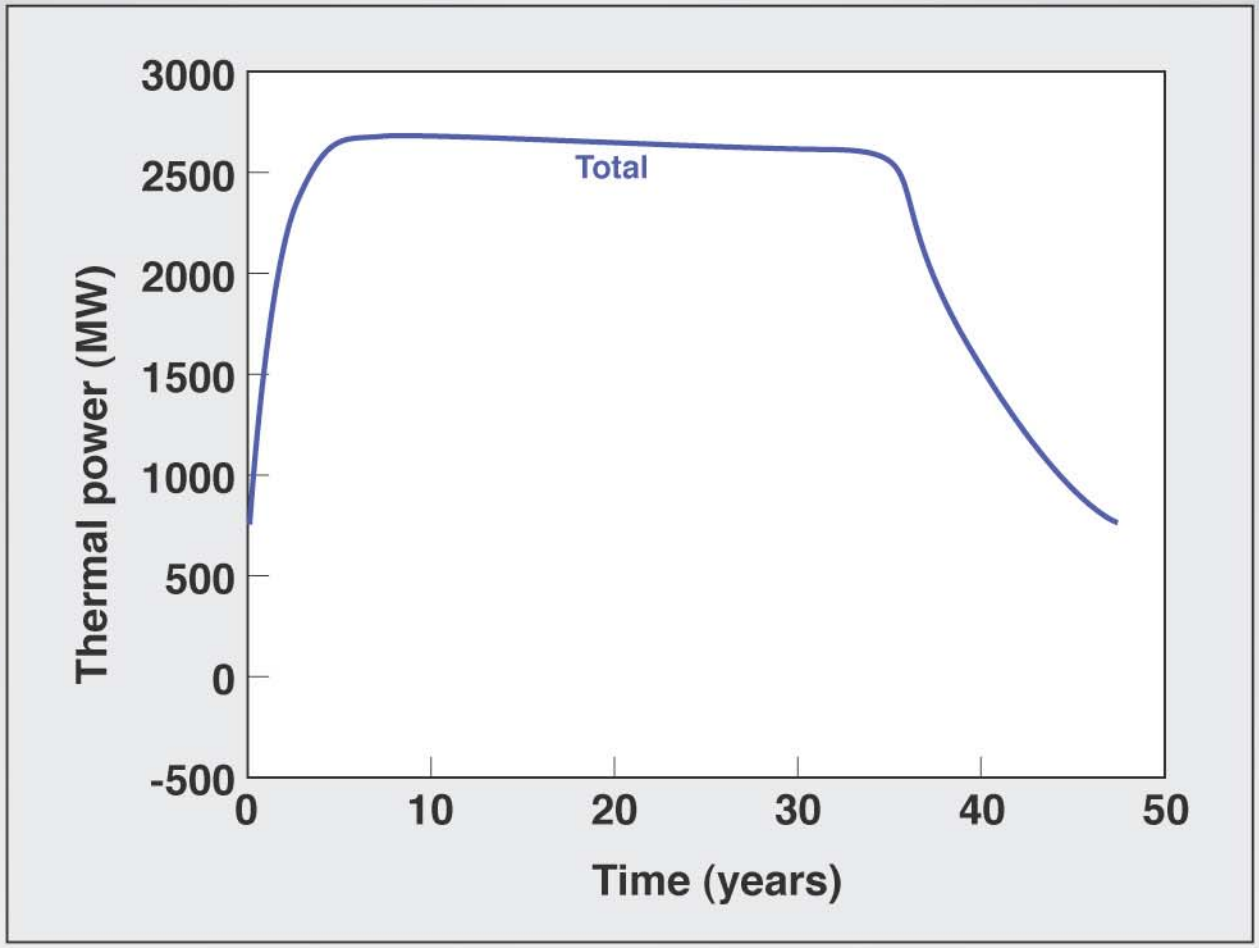
1983 MW

Parasitic Absorption

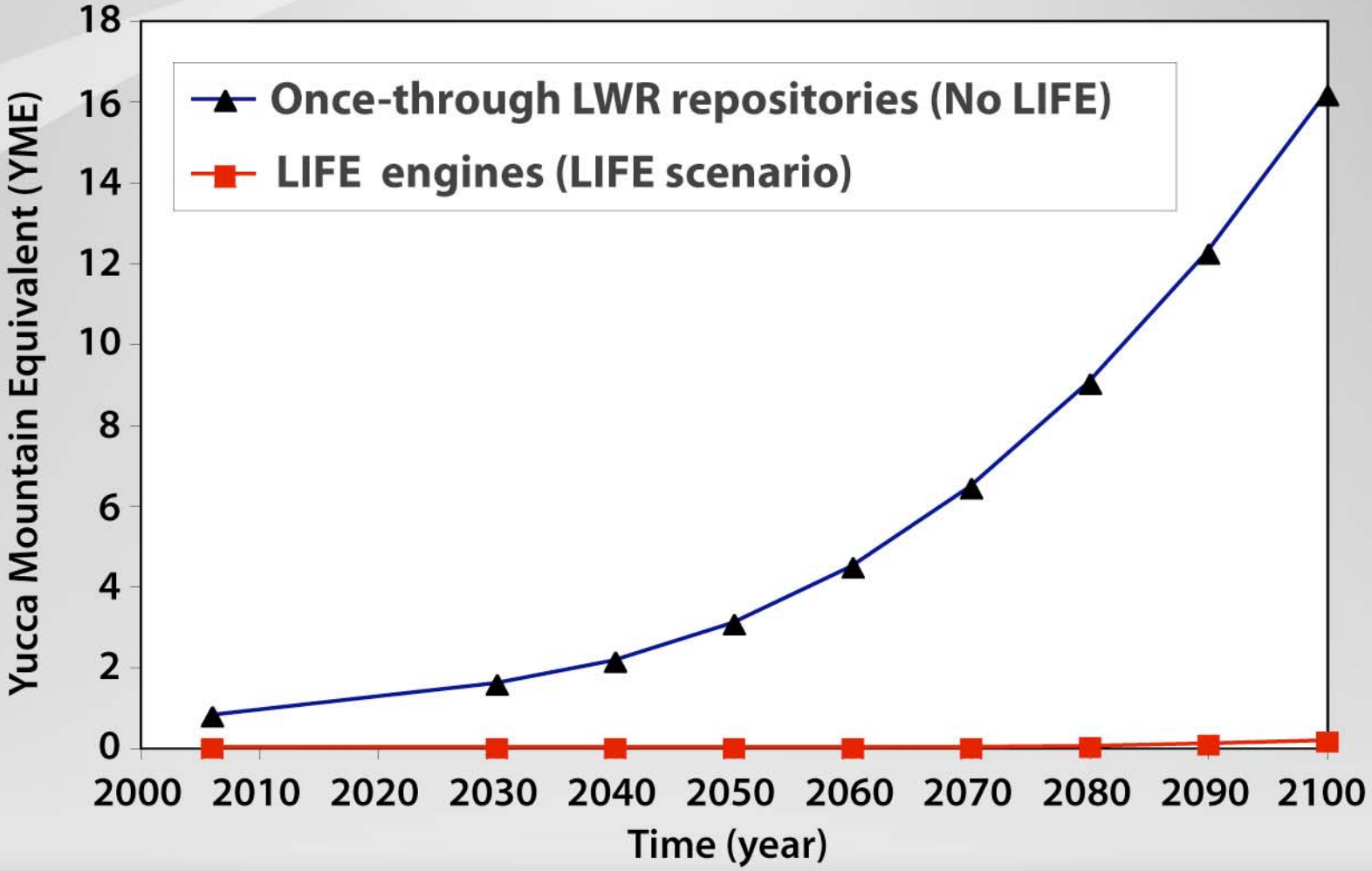
-87 MW

Waste Incineration

Starting from 40 MT of depleted U, a LIFE engine can generate 2,000 MW_{th} for 50 years without refueling or reprocessing



LIFE extends the useful service life of deep geologic repositories



Yucca Mountain Equivalent repositories through 2100 based on YMP statuatory limit (70,000 MT) and 50% U.S. electricity scenario

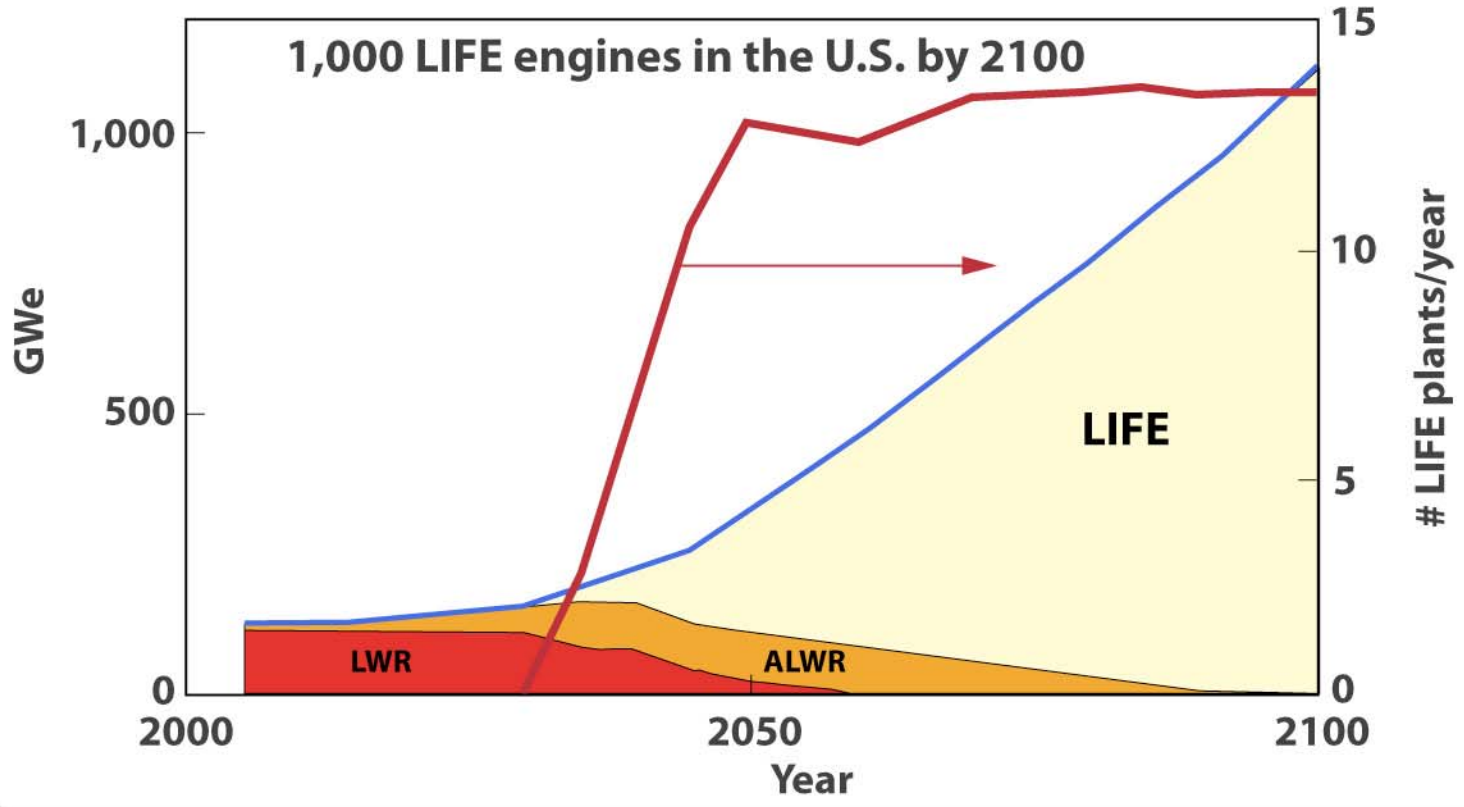
Fuel for LIFE is both readily available, nearly limitless and economical

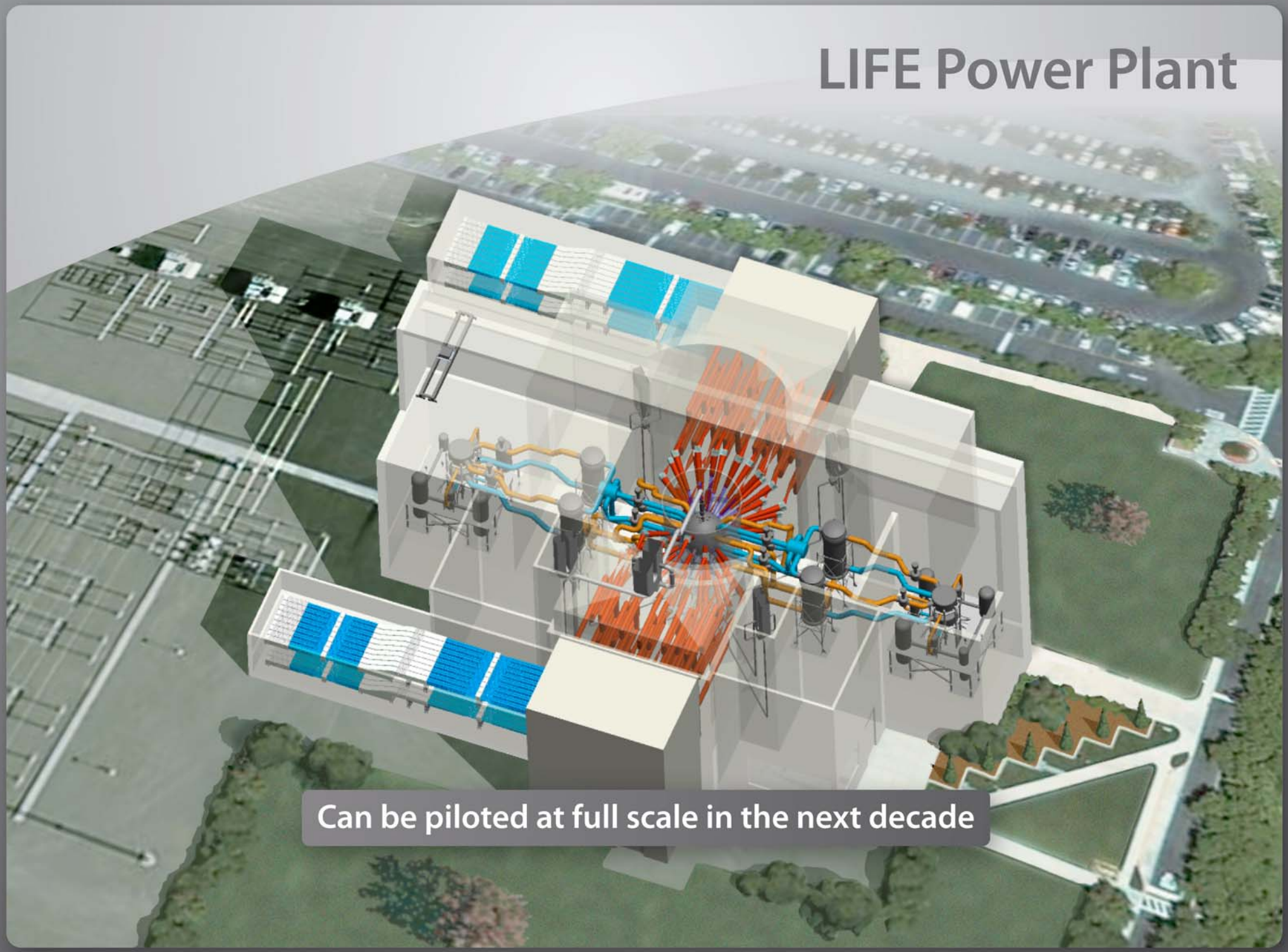
- **Waste Streams (DU) from the existing fuel cycle could provide fuel for LIFE for more than a thousand years**
- **Existing SNF from LWRs can supply 5 TWe-yrs, which is the entire U.S. electricity demand from now through 2100**
- **The accumulated SNF through the end of the century can provide U.S. electricity needs beyond 2100 (2 to 2.5 TWe) for another hundred years**
- **The DU could supply over 2 TWe for an additional thousand years**

This is $1,000T of energy at today's price (a.k.a. million-billion dollars)

By 2030, LIFE could begin to provide the majority of U.S. baseload electricity demand into the existing grid

Scenario for 50% of projected U.S. electricity demand (1 TWe) by 2100 supplied by LIFE engines burning DU and/or SNF



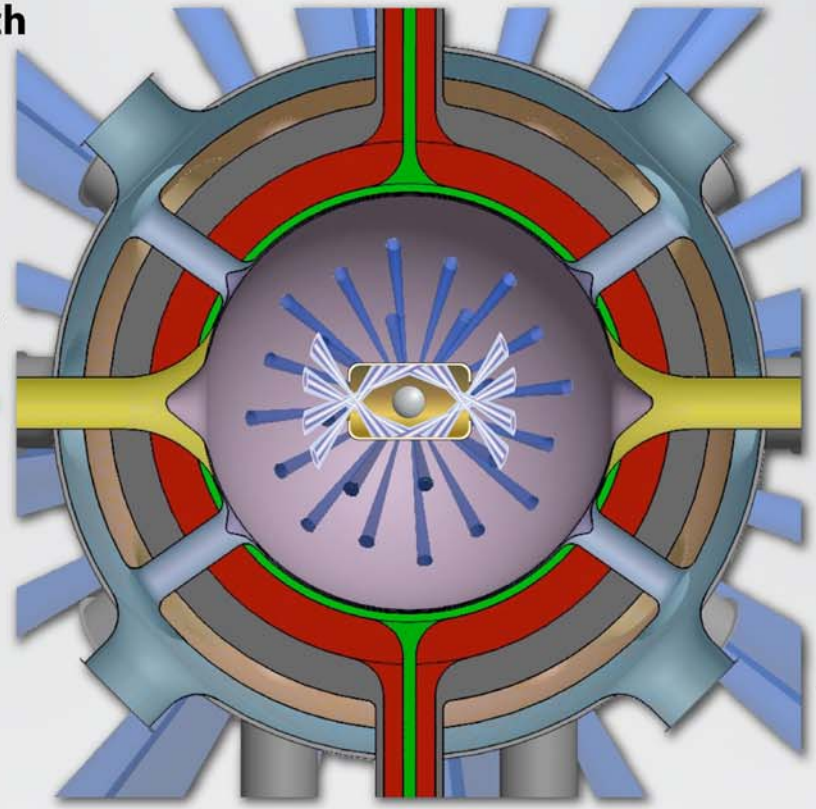

LIFE Power Plant
Can be piloted at full scale in the next decade

The Baseline, NIF-based LIFE does face technical and scientific challenges

Target production at
15 Hz @ ~ 30¢ each

Target injection

Manage fusion
environment



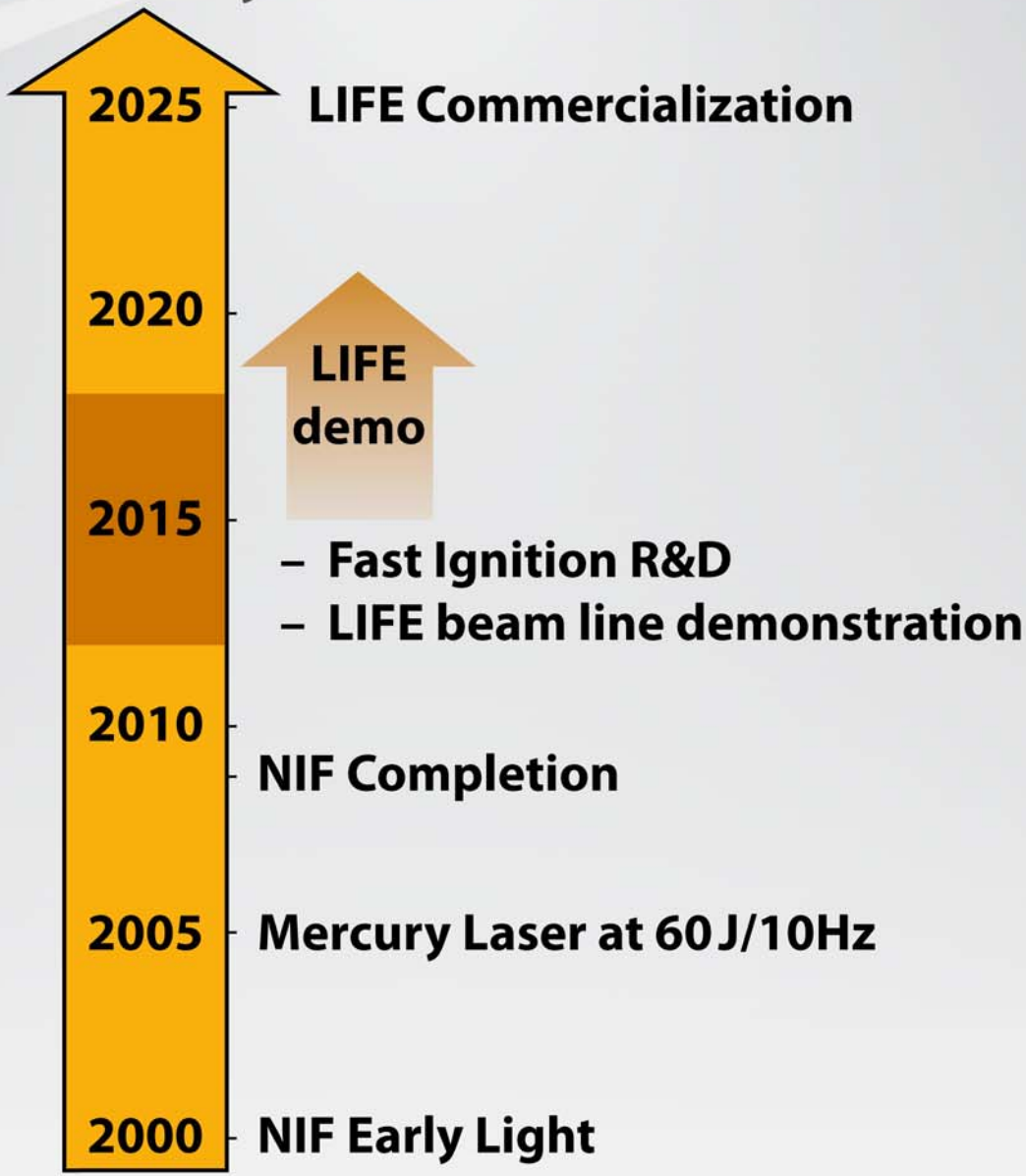
Low cost 1-1.5 MJ,
10-15 Hz 10-15% laser

1st wall must survive
~ 5 (ideally 10) years

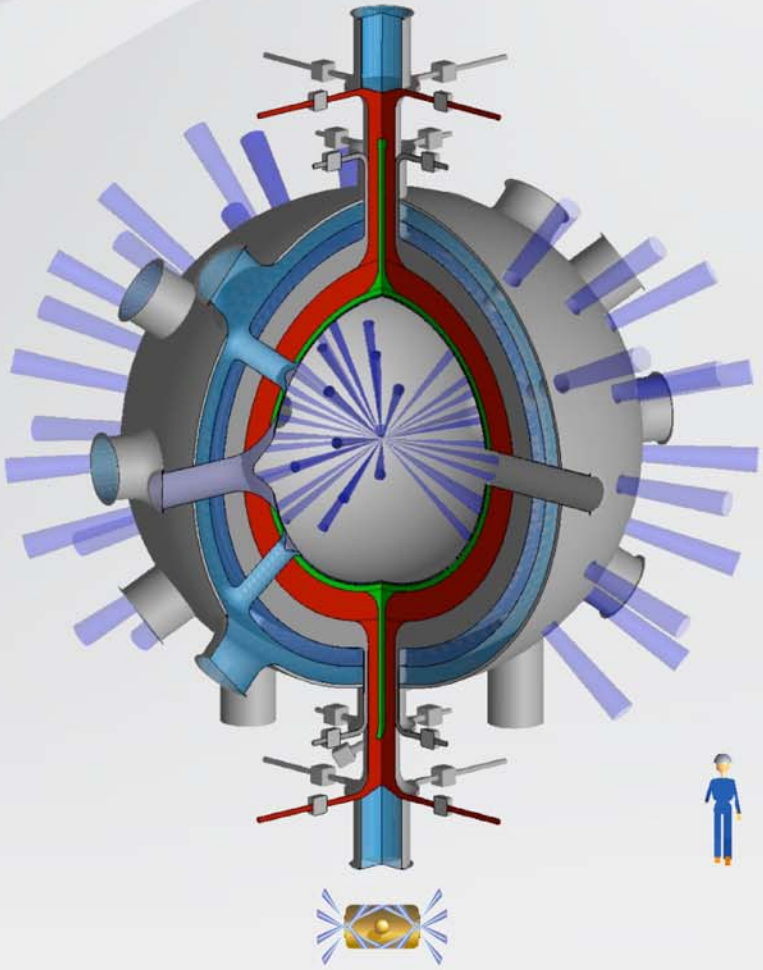
Robust Hot Spot yield
w/LIFE-relevant targets

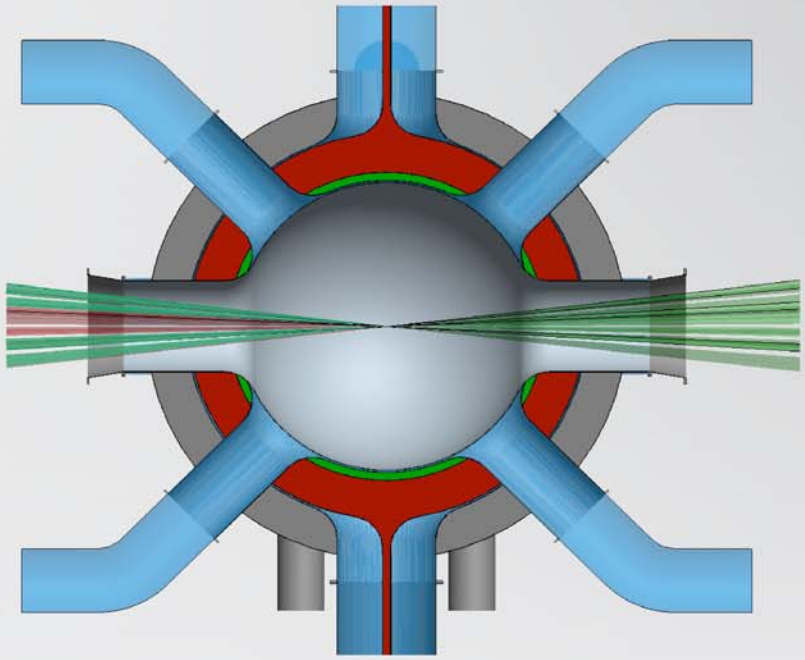
99% burn-up of fuel
without re-fabrication
or reprocessing

Leveraging the NIF provides a near-term pathway for sustainable clean energy



Fast Ignition also offers the possibility of more attractive chamber options

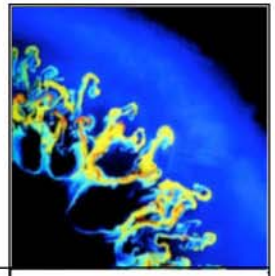
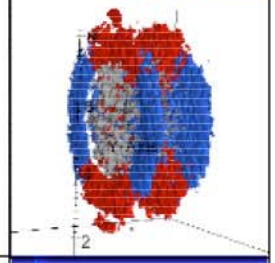
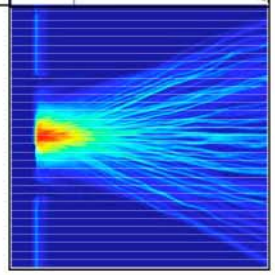
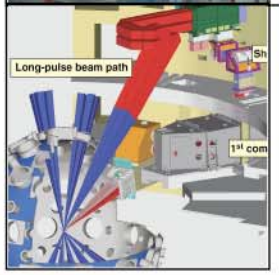




OFES supports development of computational tools for modeling fast ignition physics

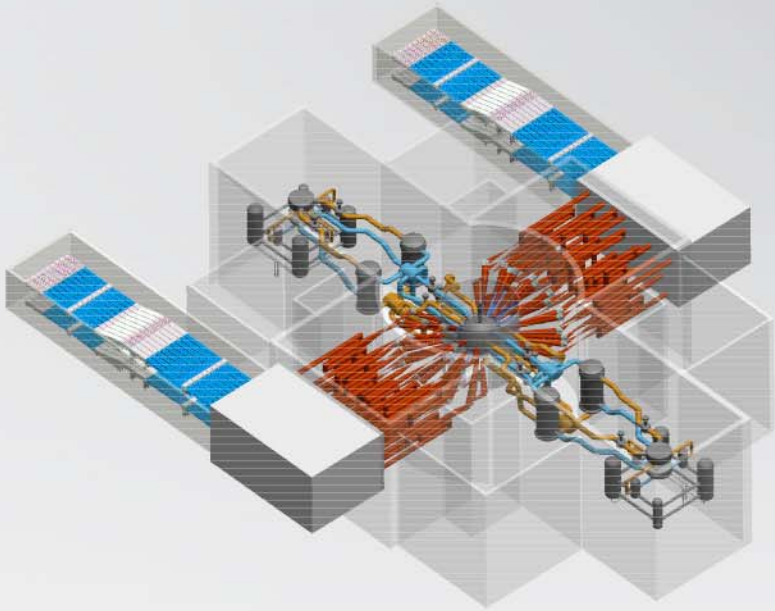
Create an experimentally validated modeling platform that can handle all of the necessary laser-plasma interaction physics required to support and design the next generation of HED and FI experiments at NIF ARC scale

State-of-the-art codes ⟺ **Experiment benchmarking**

3D Rad-Hydro code—HYDRA Hydrodynamics, radiation transport, EOS, ionisation			**TITAN** LLNL 200J, 0.5ps in 1 beam
3D PIC code—PSC Relativistic laser absorption, electron generation, electromagnetic fields			**OMEGA EP** LLE 5.2kJ, 10ps in 2 beams
3D Hybrid-PIC—LSP Self-consistent electron transport, field generation, large-scale plasmas			**NIF ARC** LLNL 10kJ, 10ps in 8 beams

Technical expertise supported by OFES will significantly contribute to LIFE

- Fusion chamber design
  - — Molten salt coolant (and possible liquid fuel version of LIFE)
  - — Tritium breeding, recovery, reprocessing
  - — Chamber/driver interface (optics protection, etc.)
  - — Safety analysis
  - — Systems modeling
  - — Overall design integration
- Target physics
  - — Fast ignition, development of validated simulation tools
  - — Proposal for additional funding submitted to OFES



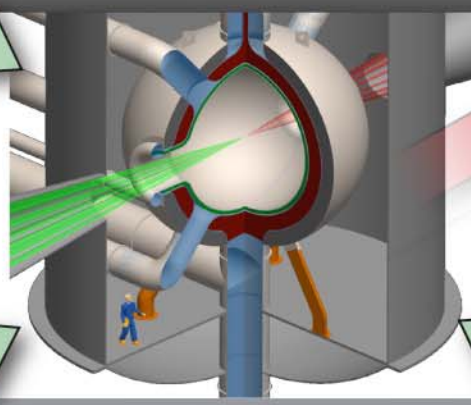
LIFE Power Plant

LIFE can provide clean energy soon and will enable fusion energy for the future

Fission

Now

LIFE



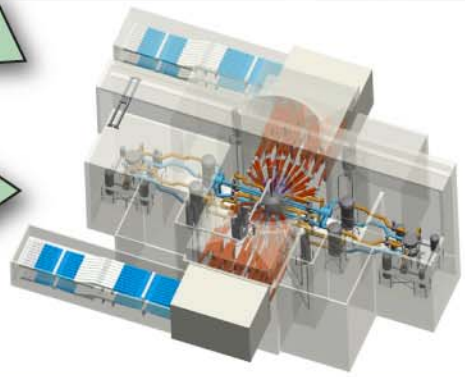
2020

Power on the grid

NIF

Now

Pure Fusion



>2020

LIFE: Laser Inertial Fusion-Fission Energy

- Sustainable carbon-free energy
- Burns depleted uranium, SNF and excess weapons grade plutonium
- Always subcritical and passively safe
- Minimizes need for repositories
- No enrichment
- Significant non-proliferation advantage