Helion

The Future of Energy

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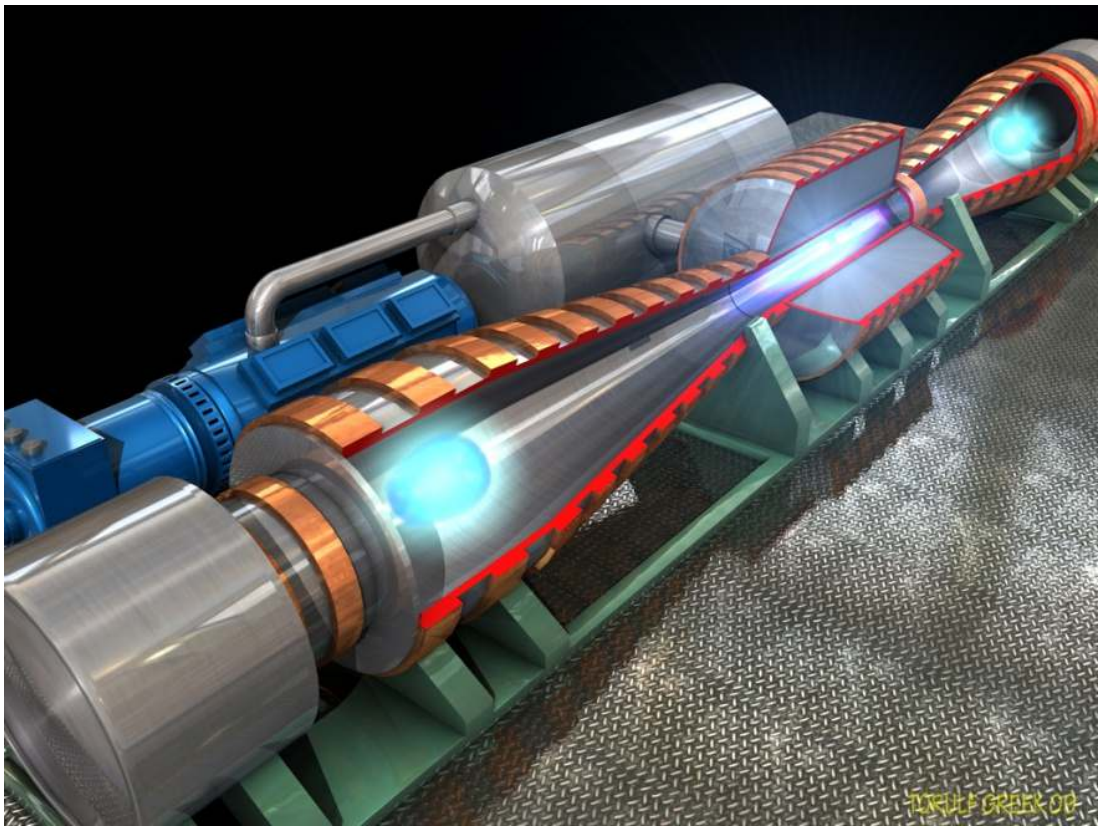
Helion Energy



We aim to build the world's first commercial fusion power plant

What is Fusion?

- ***Nuclear Fusion*** **is the energy-producing process taking place in the core of the Sun and stars**
- **The core temperature of the *Sun* is about 15 million °C. At these temperatures *hydrogen* nuclei fuse to give *Helium and Energy*. The energy sustains life on Earth via sunlight**

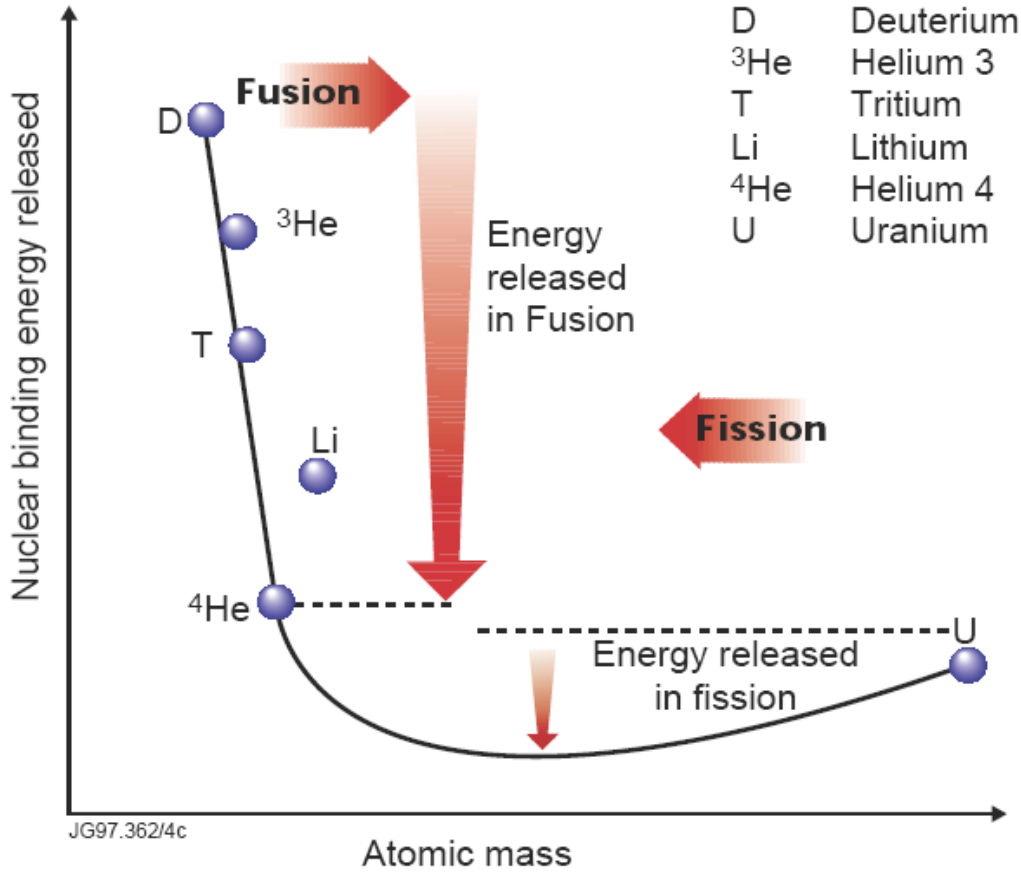
Energy Released by Nuclear Reactions

- ***Light nuclei*** **(hydrogen, helium) release energy when they fuse (Fusion)**
- **The resulting nuclei weigh less than the parent nuclei**

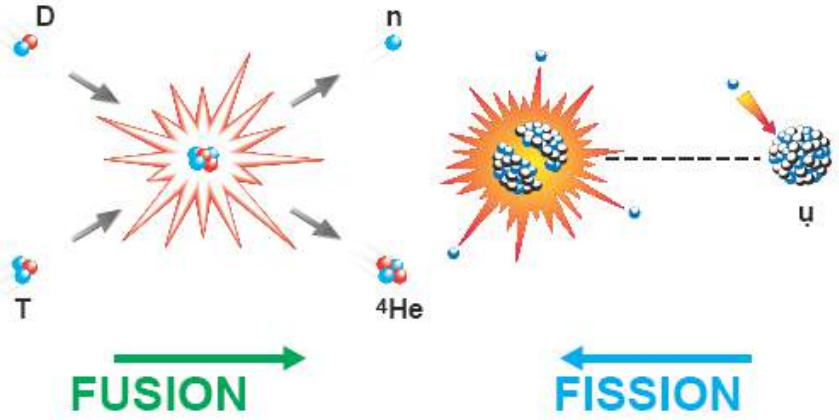
- **Heavy nuclei (Uranium) release energy when they split (Nuclear Fission)**
- **The collection of product nuclei weigh less than the original nucleus**

Energy Released by Nuclear Fusion and Fission

- ***Fusion reactions*** **release much higher energies than** ***Fission reactions*** **per reaction**



D	Deuterium
^{3}He	Helium 3
T	Tritium
Li	Lithium
^{4}He	Helium 4
U	Uranium



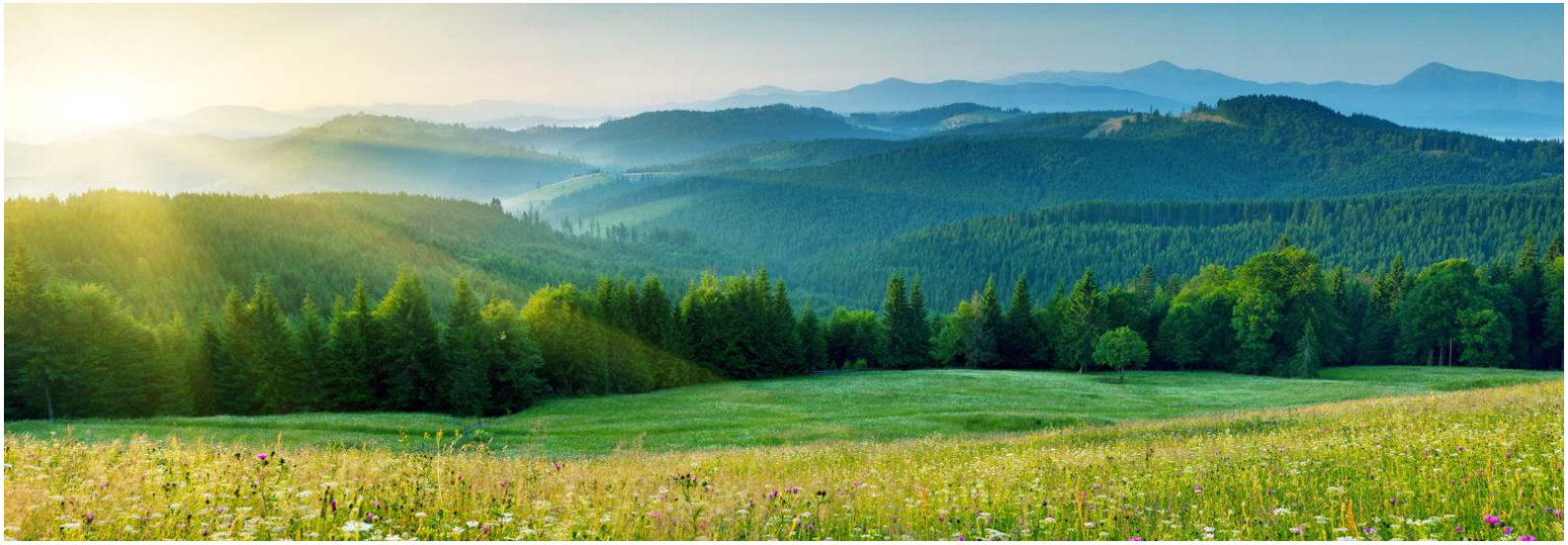
Fusion Energy – Advantages

- **Massive energy content = low cost**
- **Fuel comes from water and is abundant**
- **No catastrophic failure or proliferation concerns**

Fusion Energy – Disadvantages

- **Fusion reaction is difficult to start!**
  - High temperatures (Millions of degrees) in a pure High Vacuum environment are required
  - ***Technically complex*** and ***high capital cost*** reactors are necessary
- **Massive Research and Development has been needed to bring concept to fruition**
  - The physics is well understoond, the engineering and development timescales are very long (20 to 40 years)

Fusion's Promise



What it means:

- Zero GHG, zero hazardous waste
- Perfect complement to existing renewable resources
- Sufficient fuel to power the planet for millenia
- A totally transformative technology (and industry)

Fusion: Clean baseload power competitive in today's market at projected <$0.02/kWHr

Difference between Fusion and Nuclear Fission

Fundamental energy extraction process is different

Fusion has abundant, easy to access fuel

Currently a much easier regulatory, licensing, and inventory challenge

Difference between Fusion and Nuclear Fission

Fundamentally no meltdown scenarios

Fuels and byproducts do not include special nuclear materials (Tritium)

No proliferation concerns that we know of

Helion Team

Dr. David Kirtley, CEO

NSF, DoD, NASA Fellow, $10+ M in grants
13 years in fusion, Aerospace & Nuclear PI, PM

Prof. John Slough, CSO

30 years in fusion, $15 M grants, Founder of MSNW

Chris Pihl, CTO

10 years in fusion, 23 years industry, Founder of PPS

Dr. George Votroubek, Principle Scientist

16 years in fusion, plasma physicist

Advisors and Team

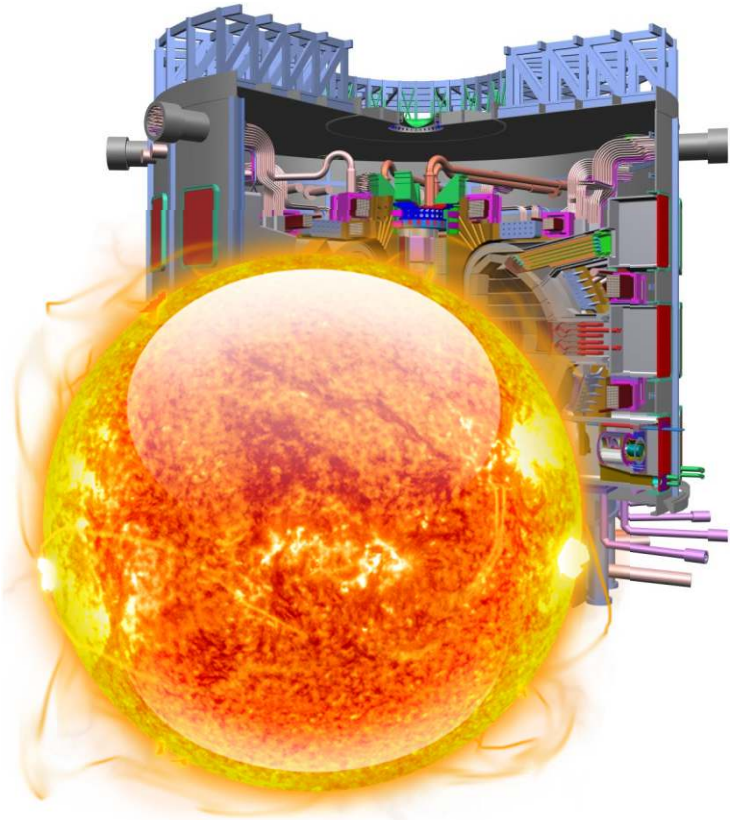
James LoGerfo– Institutional VC, Energy Generation Advisor
Legal – Seed IP (IP), Cooley (Business), Dorsey (Export), K+L Gates (Policy)
Mark Van Order- HP Strategic Partner and Business Development Expert

Started With Commercialization Objective

Engineer a commercially practical & profitable reactor

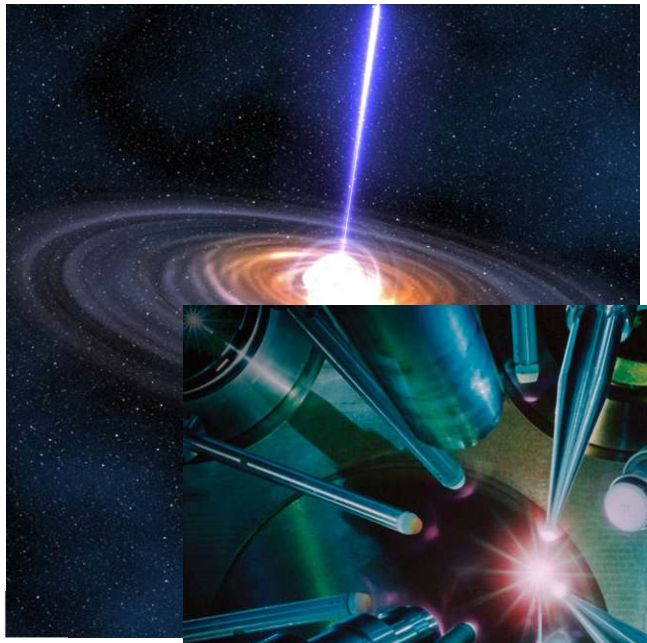
Developed by Engineers to be commercially practical

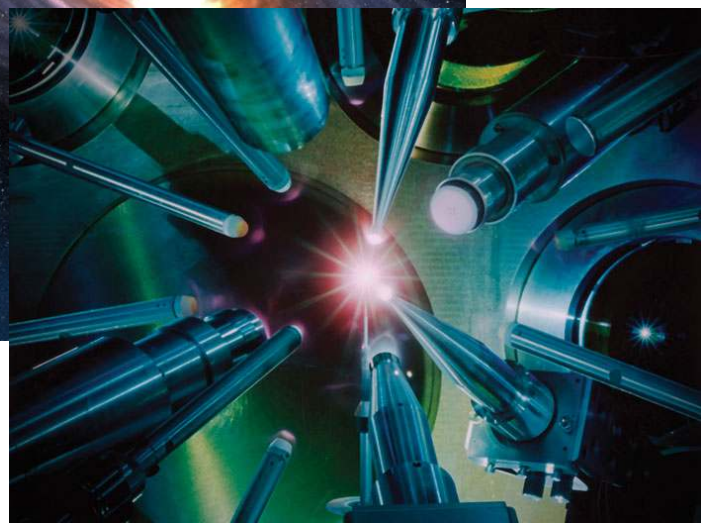
- Uses existing components
- Inherently clean, safe, no byproducts
- Meets base load and peaking demands
- Low cost, rapid deployment (small, modular)



Too Big

Fundamentally large scale

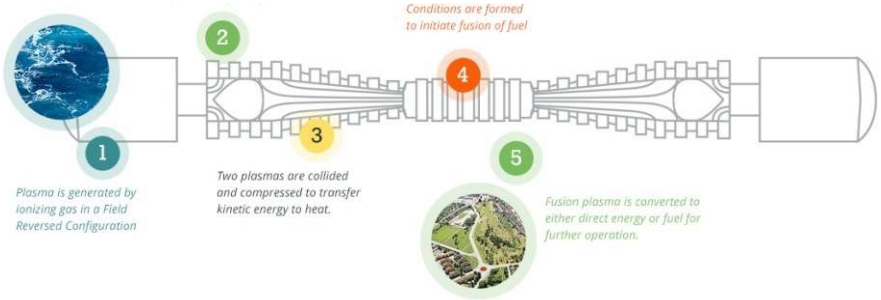




Too Hard

Fundamentally inefficient

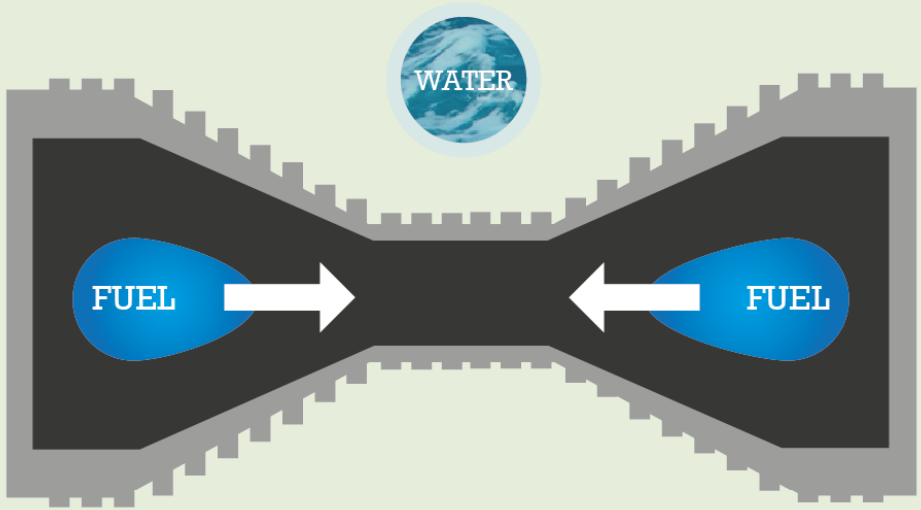
Just Right



Scalable, Low Cost, and Efficient

1

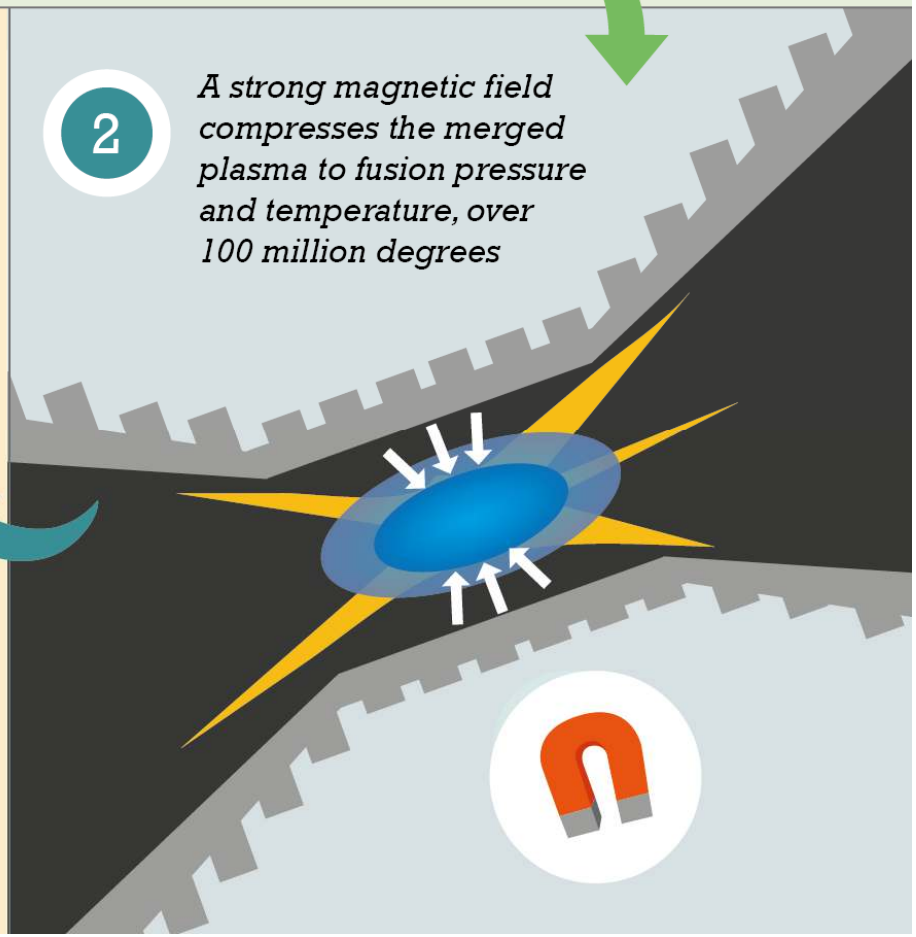
Deuterium fuel extracted from water, and helium from the engine's exhaust, is injected and heated until it becomes a plasma



Pulsed magnetic fields accelerate the plasma into the burn chamber at over 1 million mph

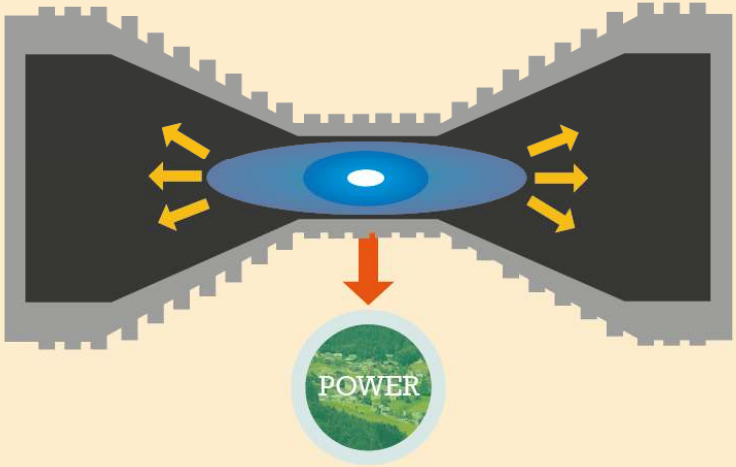
2

A strong magnetic field compresses the merged plasma to fusion pressure and temperature, over 100 million degrees



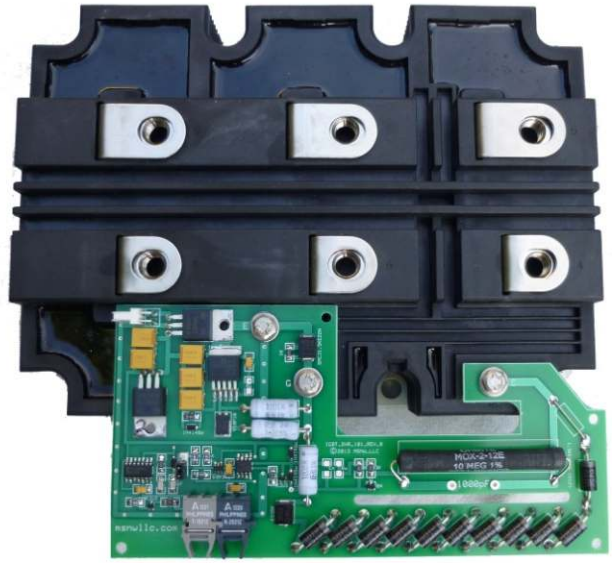
3

At high temperature the deuterium and helium nuclei fuse, releasing charged particles that push back on the compressing magnetic field



The expanding plasma is directly converted into electricity to operate the next cycle once a second

Modern electronics make Magnetic Compression possible

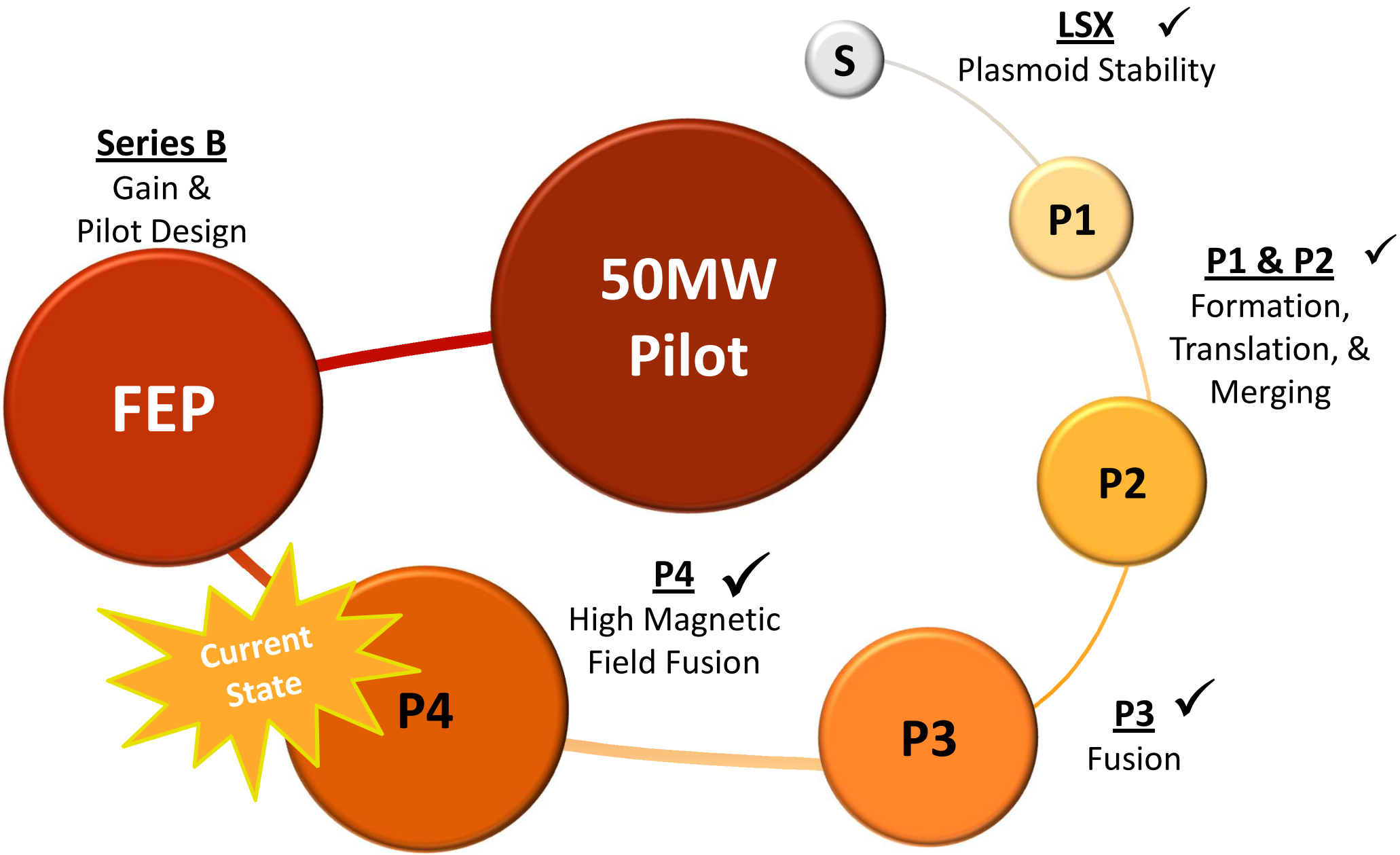


And now we can do this:

4th Operational Prototype

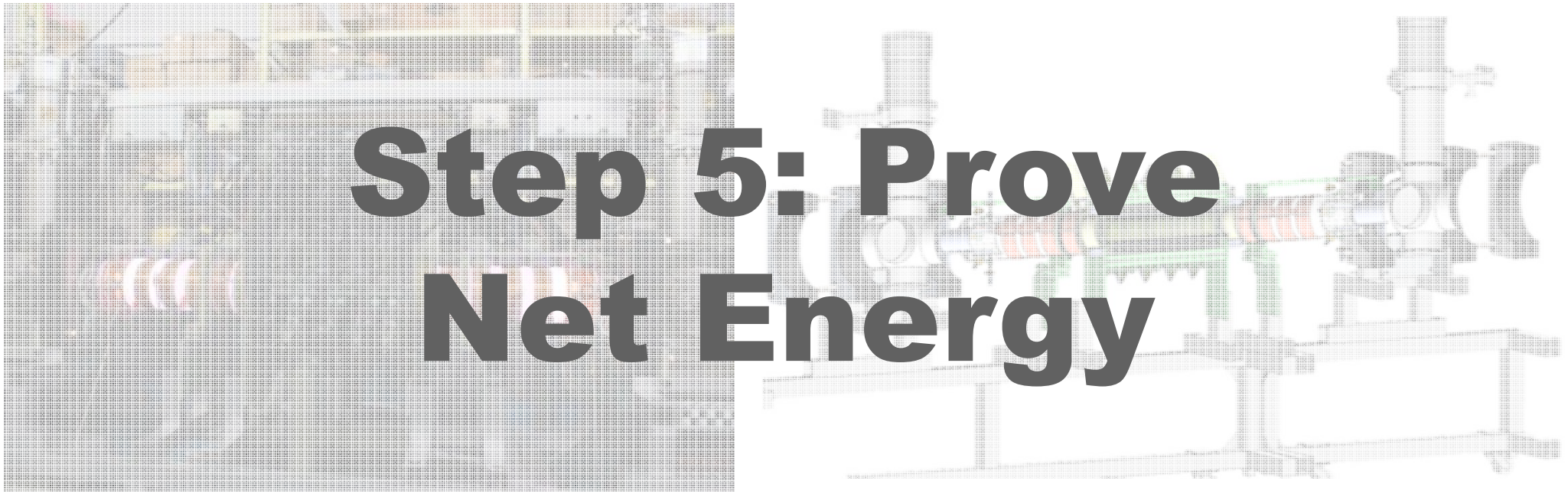
5 keV Deuterium

Path to Commercial Pilot



FEP – Next Step

Fusion Engine Prototype



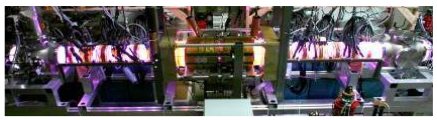
Demonstrate Net Energy Generation

- Combines Stability, Merging, & High Magnetic Field Fusion at scale for Net Fusion Gain
- Design 1st Commercial Plant

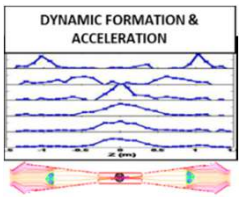
The Science

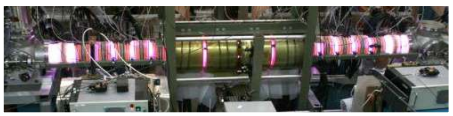
- Magneto-Inertial Fusion
  - 5+ keV ion temperature
  - **Measured D-D fusion production**

- Scientifically legitimate
  - DOE Office of Fusion Energy validation ($5M)
  - IAEA best peer reviewed fusion– 2011
  - Extensive external technical due diligence
  - 4th prototype operational in Redmond, WA

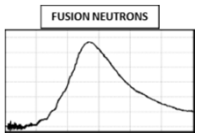


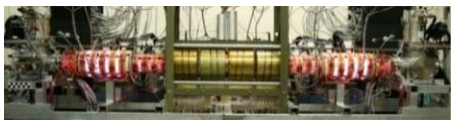
Prototype I





Prototype II





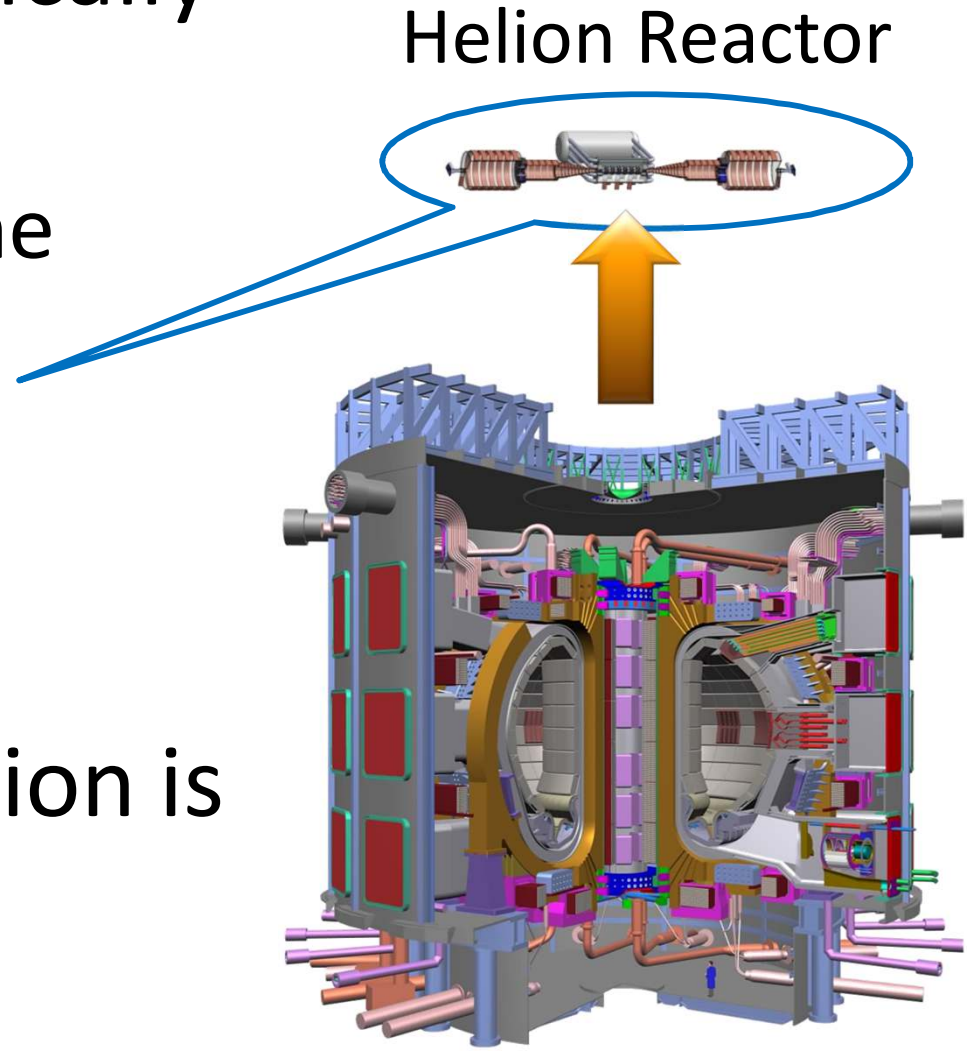
Prototype III

Key Distinctions: Physical Scale

Pulsed operation radically shrinks hardware

- 1:1,000,000 volume

Magneto-Inertial Fusion is key



Key Distinctions: Direct Energy Conversion

- High Efficiency Energy Generation
- Anywhere
- Modular design
- Zero cooling water
- No steam generation

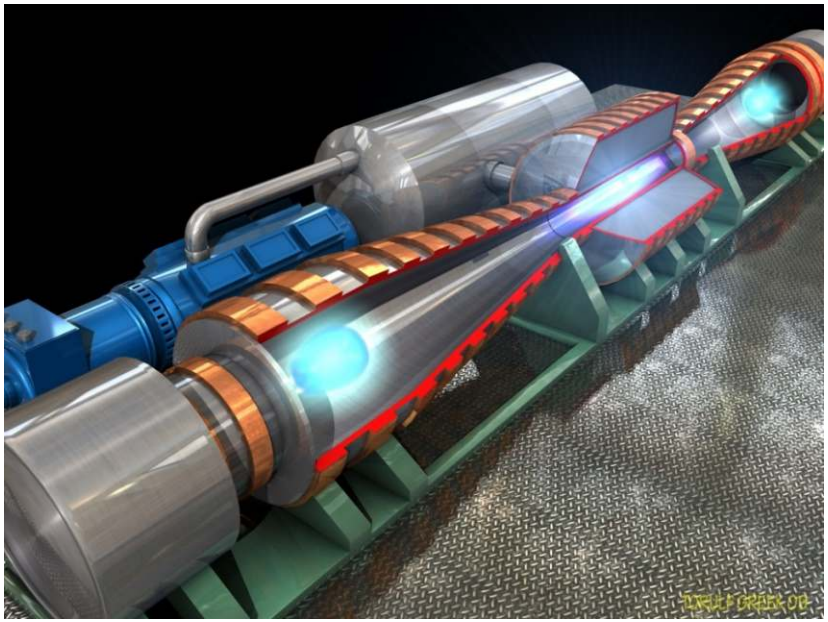
Magnetic fusion energy is directly converted to electricity at high efficiency – reducing capital, physics & TCO requirements

What we still have to do

<u>Gain Fusion!</u>

Full Scale Power Output

Pilot Plant Development



Partners

- Key Team is originally from UW
- Chief Scientist is Research Prof.

- Current Partnerships with scientific, world-class expertise

- Diligence and teaming relationships throughout DoE

- Ongoing relationship at PNNL

Investors

R&D – 2005-2013

- **DoE - $5 M in Federal Grants**
- **NASA - $1 M in Federal Contracts**

Series A – 2014- $1.5 M

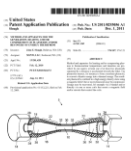
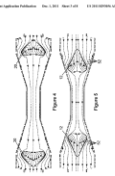
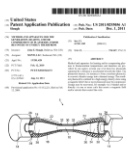
- **Mithril**
- **Y Combinator**

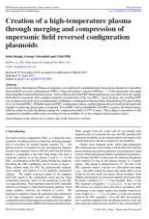
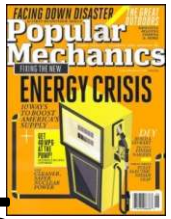
MITHRIL

"Viewed as wild success in Silicon Valley as a PNW Energy Startup"

Industry Validation

- **Competitive validation**
  - Three sequential, competitive DOE programs
- **Business validation**
  - 2013 National Cleantech Open Energy Generation
  - 2014 ARPA-E Future Energy Summit
  - Extensive external COE authentication
- **Scientific validation**
  - DOE Office of Fusion Energy validation ($5 M)
  - IAEA best peer-reviewed fusion paper – 2011
  - **External technical diligence**

Perfect Modular, Off-Grid Solution

Go To Market

Seed R&D – 2005-2013 - Lifetime, Scaling, Fusion!

Series A – 2014 - Repetitive Power, Cost

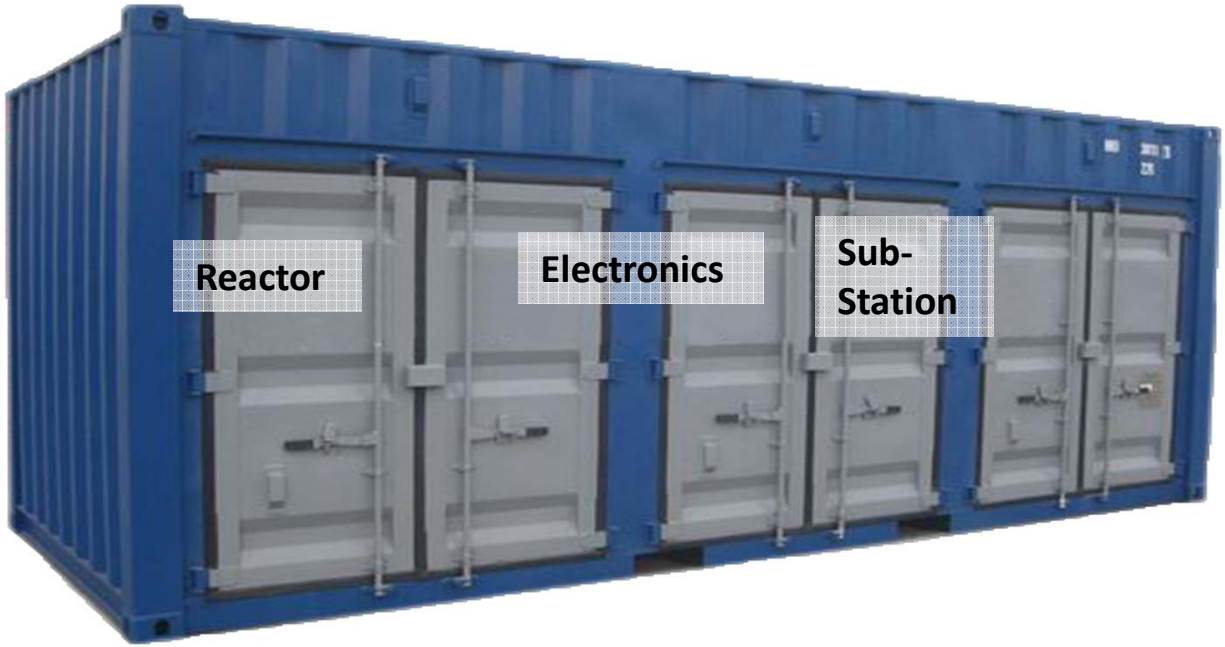
Series B – 2015-2018 - Gain Fusion, Electricity Generation

Pilot Power Plant 2018-2020 - 50 MW Electricity Generation

Full Vertical Integration - Build, Operate, Service, Sell Elect.

Commercial Power Plant

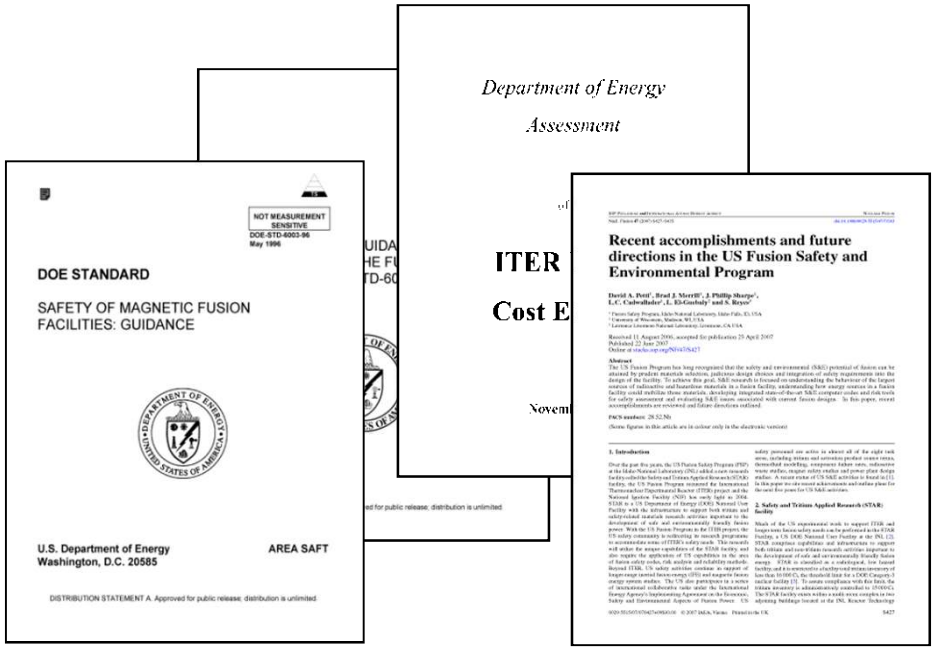
- 50 MW pilot plant is FEP follow-on
- 3 Year Development – online in 2021
- Initial electricity <$60/MW-hr (validated)
- Pilot plant is demonstration and early revenue



Licensing and Political Concerns

- Like all power plants, the regulatory and licensing process is a critical challenge
- Export Control – Commerce Dept.
- Fuel and Facility Licensing – General Licenses?
- International Licensing – IAEA

- Danger: The Policy of Fusion



What Could This Mean For Washington?

Green Jobs

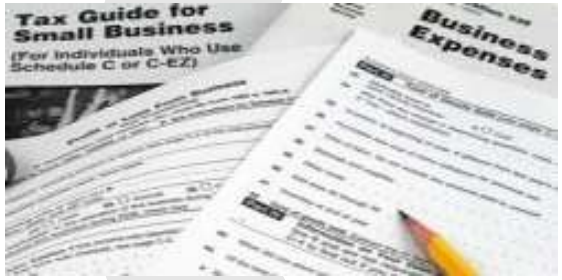
Clean Energy

Low $$ Energy

Accelerated Conversion to eVehicles

Cleantech Innovation

New Business Revenue



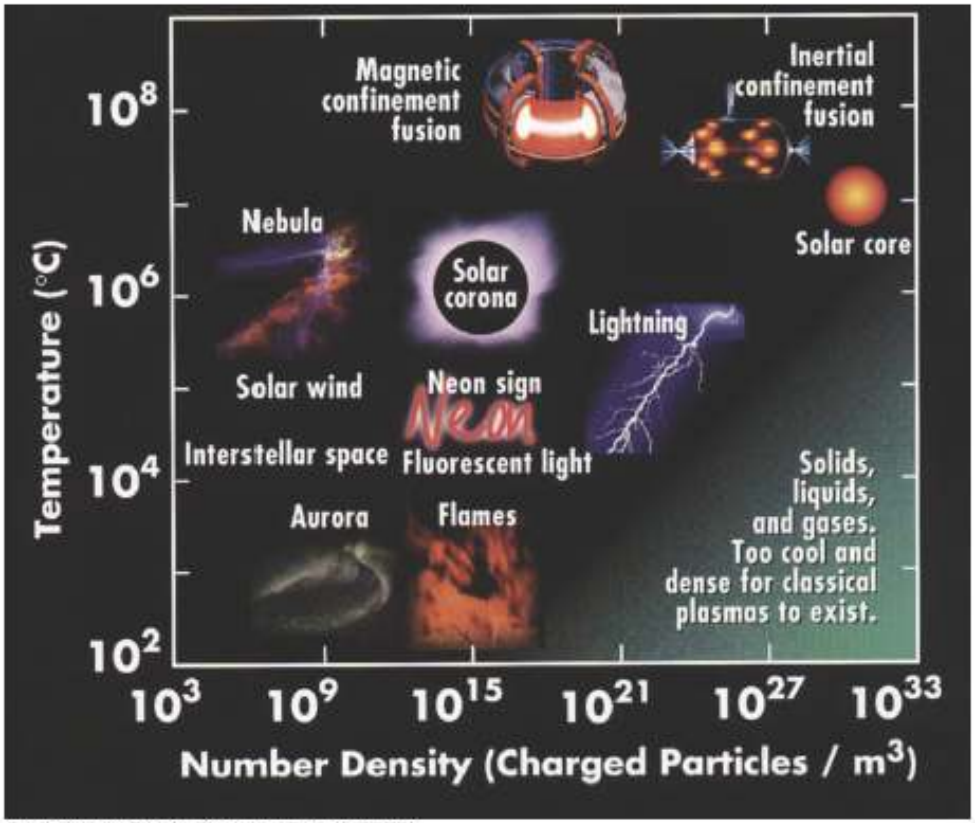
State Assistance

- **Work with State to:**
  - **Supporting R&D and Education in Washington**
  - **Reducing investor risk to bring Fed. And CA money into WA.**
  - **Collaborate on Plant Siting and Licensing**
  - **Other Opportunities**


Helion
The Future of Energy

Plasmas

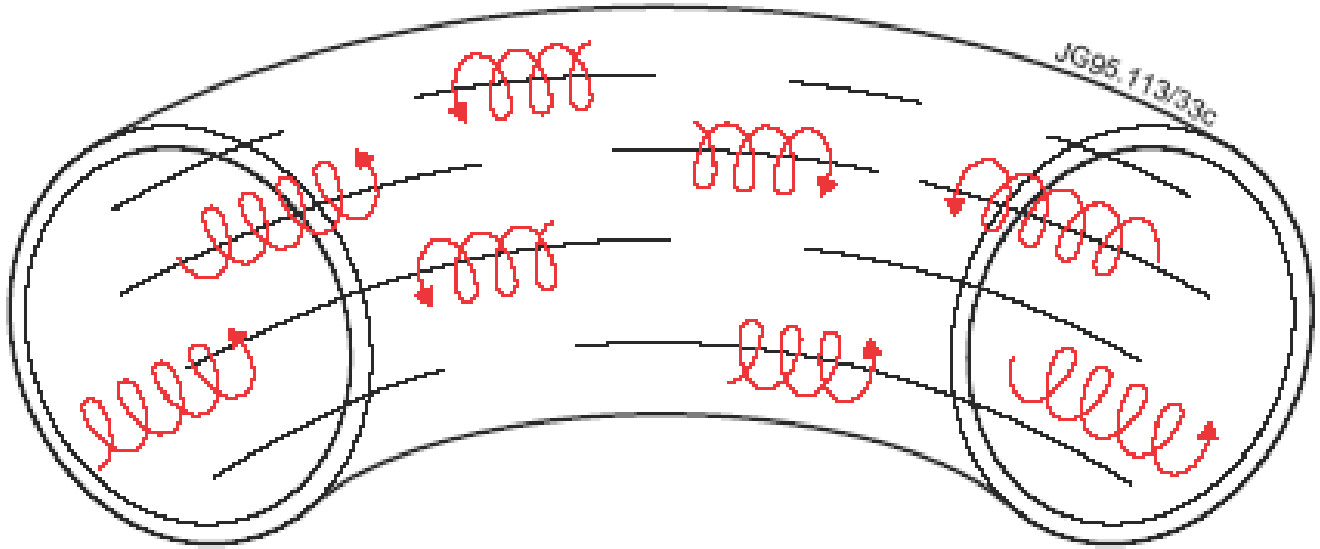
- A *Plasma* is an ionised gas. A mixture of *positive ions* and *negative electrons* with overall *charge neutrality*
- Plasmas constitute the 4th state of matter, obtained at temperatures in excess of 100,000 degrees
- Plasmas conduct *electricity* and *heat*



Contemporary Physics Education Project (CPEP)

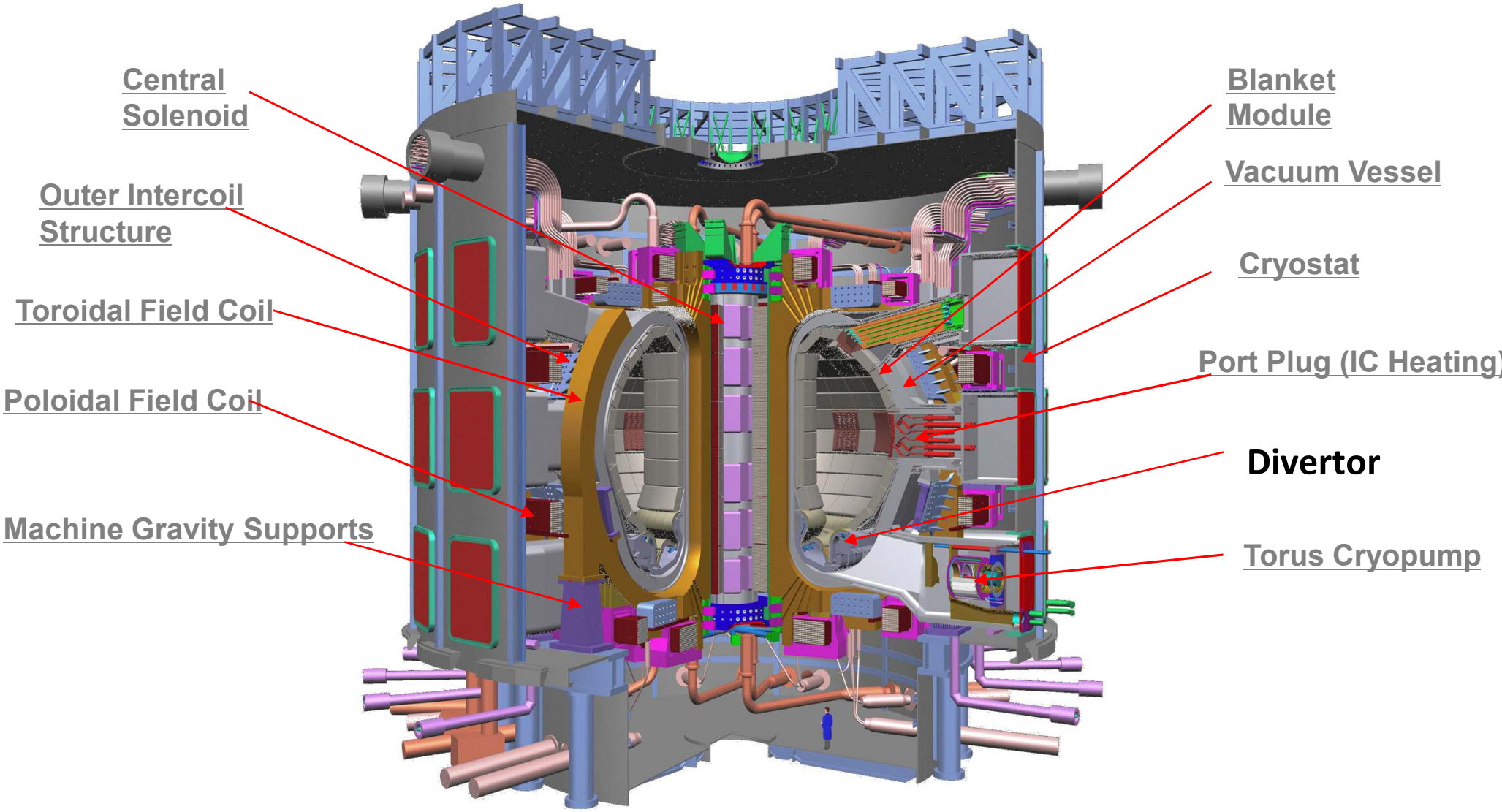
Magnetic Confinement

- ***Magnetic fields*** **cause charged particles to spiral around field lines. Plasma particles are lost to the vessel walls only by relatively slow diffusion** ***across*** **the field lines**



- ***Toroidal*** **(ring shaped) system avoids plasma hitting the end of the container**
- **The most successful Magnetic Confinement device is the** ***TOKAMAK***

ITER

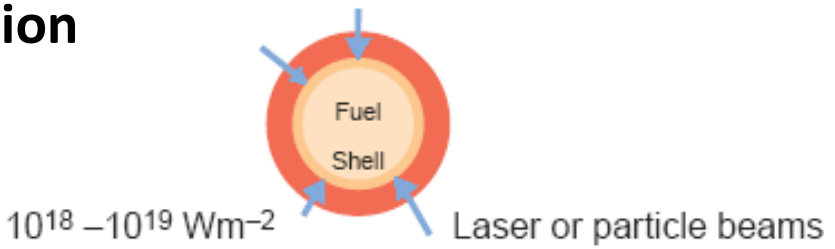


36 Nation Science Program in Cardache, France

US committed $3B, operation in 2026

Inertial Confinement

- **Laser implosion of small (3mm diameter) solid deuterium–tritium pellets produces fusion conditions**
- **Pressure generation**

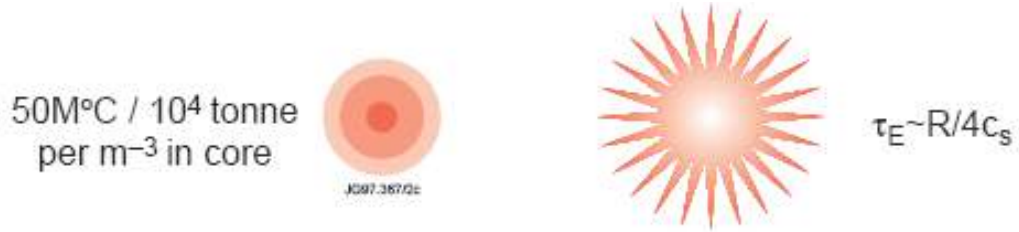


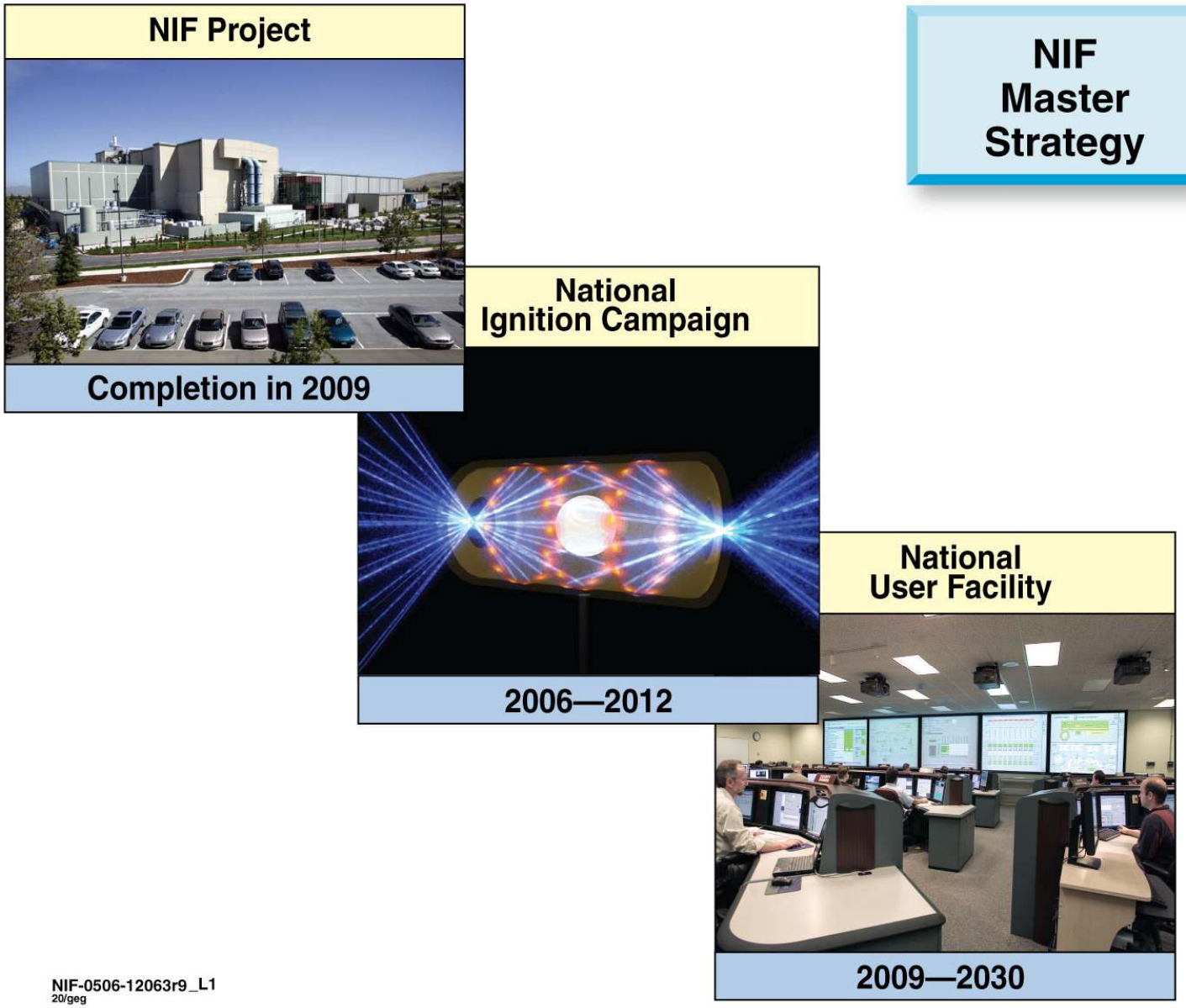
- **Compression**

  Fuel is compressed by rocket-like blow off

  200,000 million atmospheres in core

- **Ignition and burn**



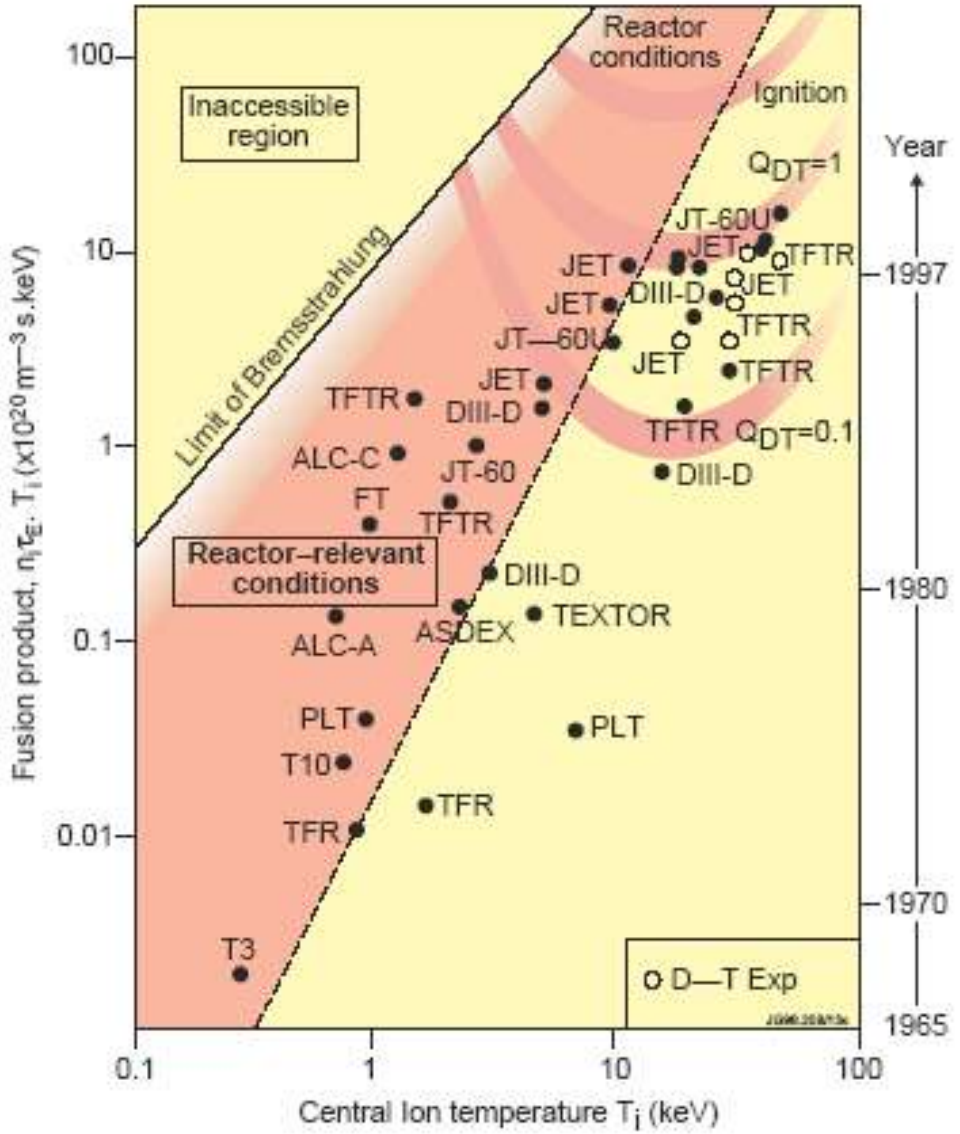


- **NNSA Funded NIF – 15 year, $7+B**

Progress towards Ignition

- **Fusion has already made more energy out then put in**
- **JET 1997**
- **NIF 2014**

Both paths, however, lead to GW-scale facilities



Why can Helion deliver?

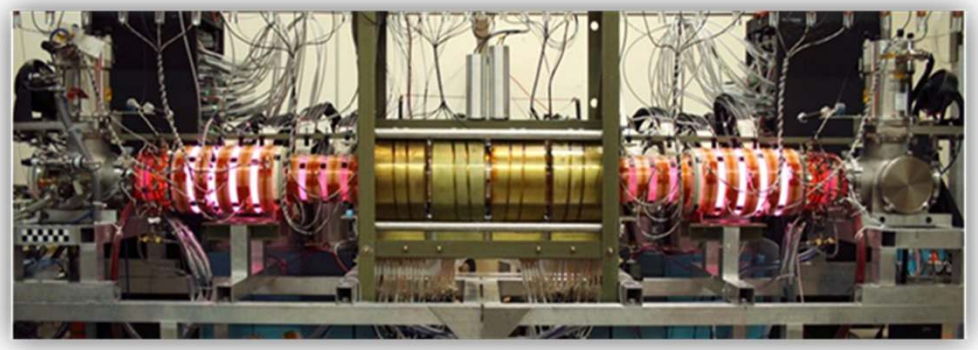
Helion Simplified the Problem

- **Merging of Magneto-Inertial Fusion Plasma**
  - Minimizes scale, time, money, complexity, & risk
- **Magnetic Compression**
- **Direct Energy Recovery**

Key Distinctions: Magnetic Compression

- Fuel is efficiently compressed
- No Mechanical points of failure
- No Lasers or Superconductors

Demonstrated Deuterium Fusion 2010

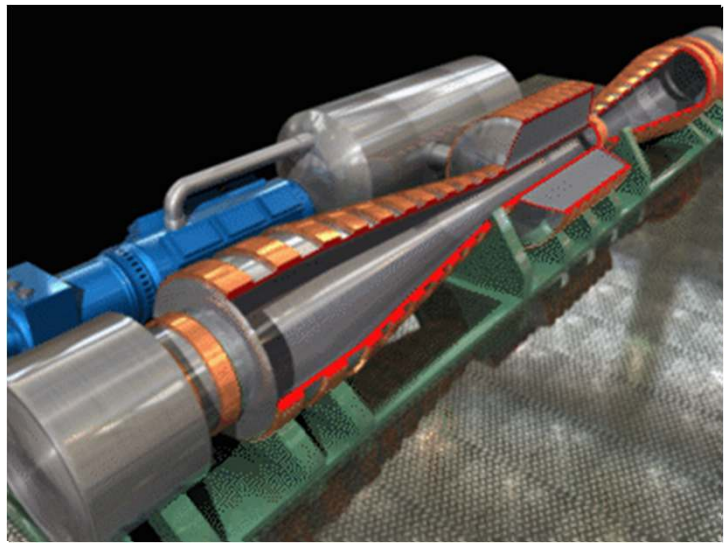


Reactor repetitively heats & compresses a plasma generating fusion pulses at 1 Hz without structural or thermal issues

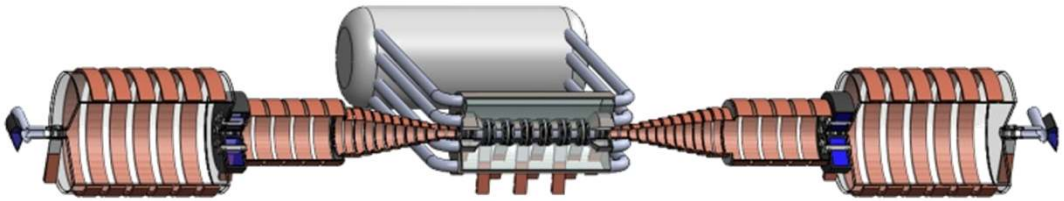

Helion
The Future of Energy

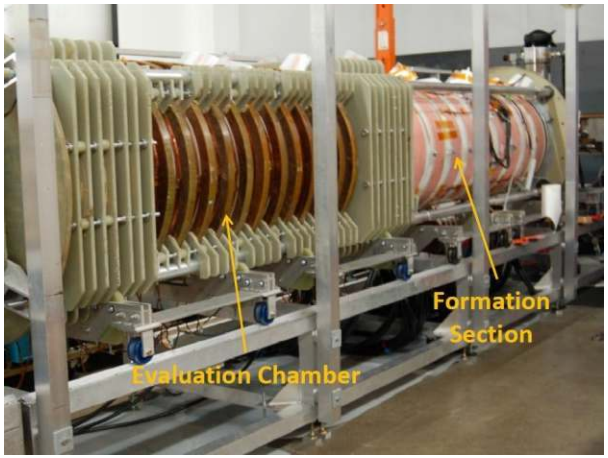
The Fusion Engine – How It Works

1. **Formation** - Fuel is added and heated forming a plasma at each end



Artist's animation of the Fusion Engine



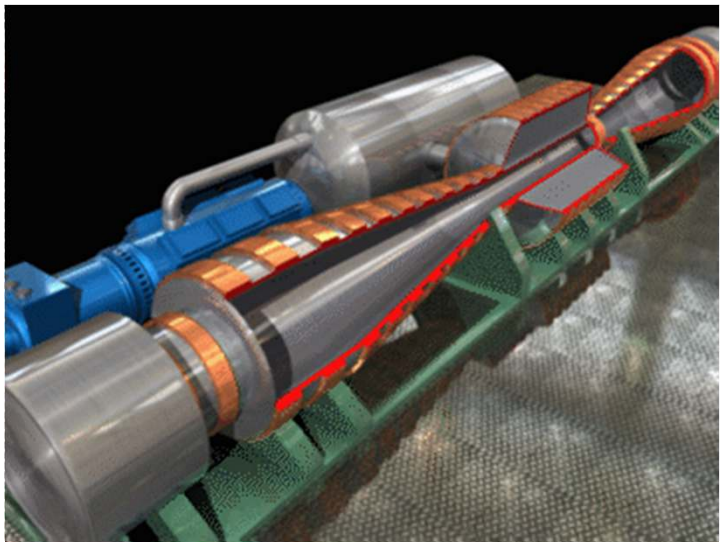


Full Scale Formation Demonstrated (2005)

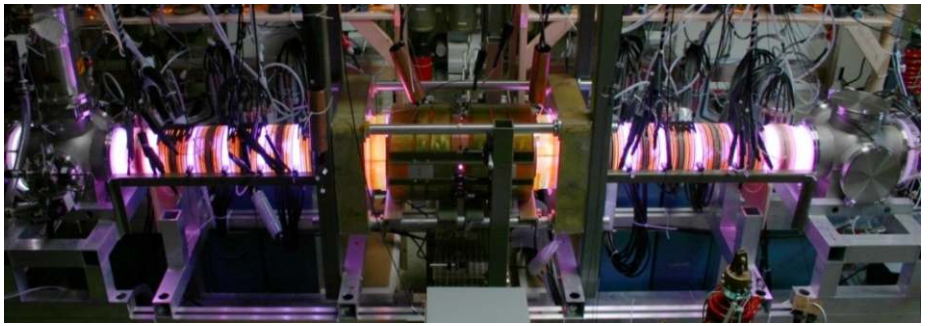
The Fusion Engine – How It Works

1. **Formation** - Fuel is added and heated forming a plasma at each end

2. **Acceleration** - Plasmoids are magnetically injected into and merge in the burn chamber



Artist's animation of the Fusion Engine



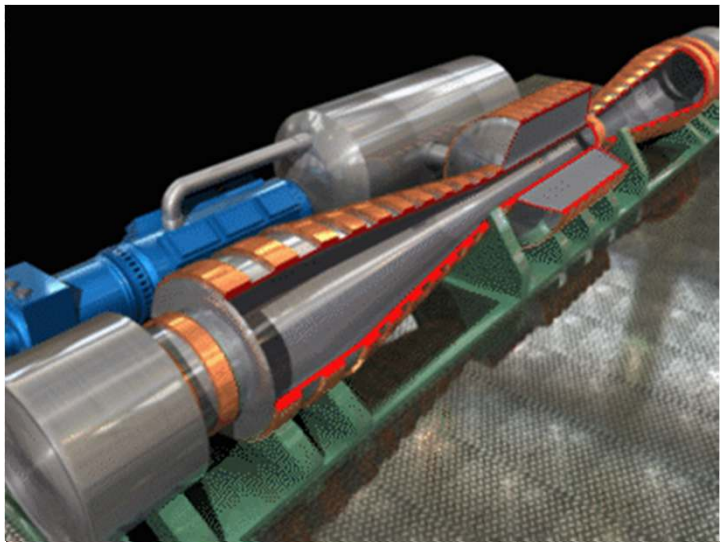
Acceleration and Merging Demonstrated (2008)

The Fusion Engine – How It Works

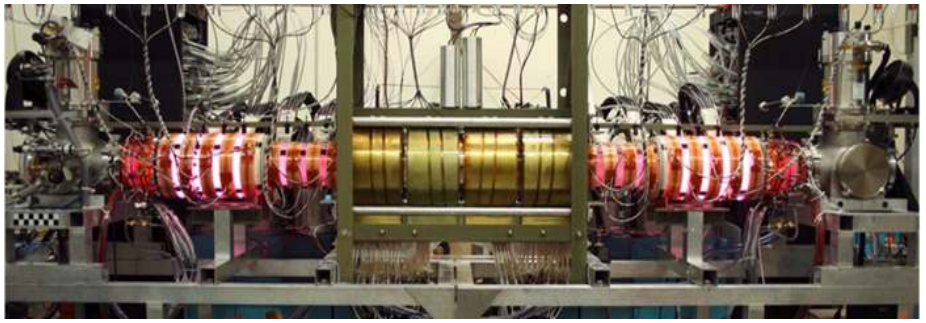
1. **Formation** - Fuel is added and heated forming a plasma at each end

2. **Acceleration** - Plasmoids are magnetically injected into and merge in the burn chamber

3. **Compression**- Plasmoid is magnetically compressed to fusion conditions



Artist's animation of the Fusion Engine



Compression and Fusion Demonstrated (2011)

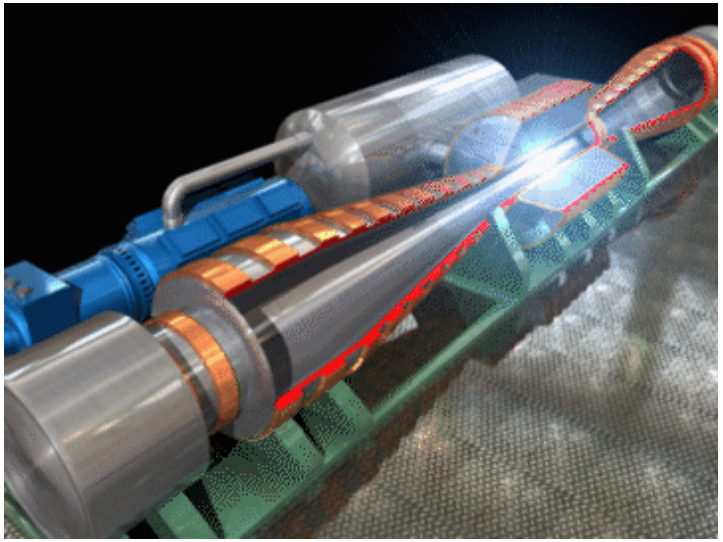
The Fusion Engine – How It Works

1. **Formation** - Fuel is added and heated forming a plasma at each end

2. **Acceleration** - Plasmoids are magnetically injected into and merge in the burn chamber

3. **Compression**- Plasmoid is magnetically compressed to fusion conditions

4. **Fusion** - Fusion burn occurs with reaction products heating and expanding



Artist's animation of the Fusion Engine

Current operation exceeds 5 keV, best in USA

High Temperature Fusion Demonstrated (2014)

The Fusion Engine – How It Works

1. **Formation** - Fuel is added and heated forming a plasma at each end

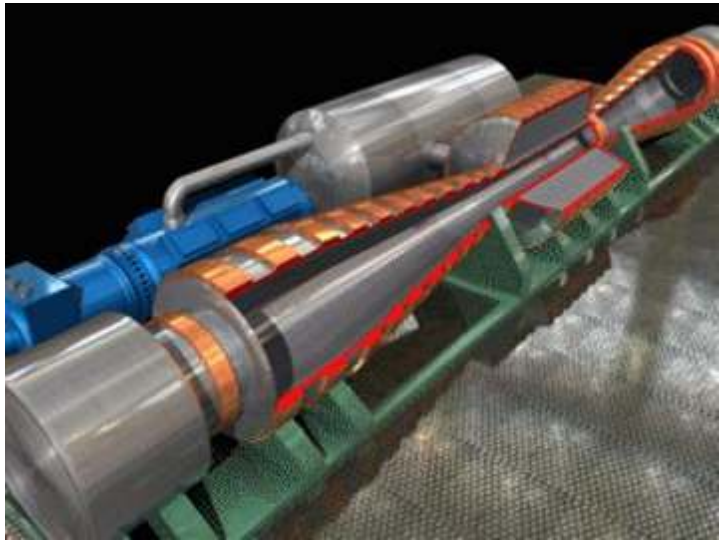
2. **Acceleration** - Plasmoids are magnetically injected into and merge in the burn chamber

3. **Compression**- Plasmoid is magnetically compressed to fusion conditions

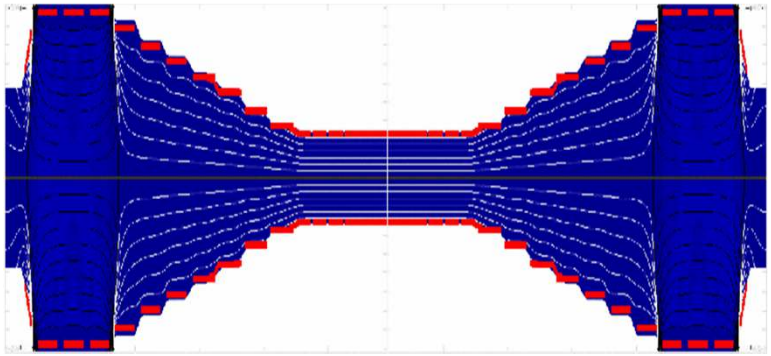
4. **Fusion** - Fusion burn occurs with reaction products heating and expanding

5. **Energy Generation** **-** Plasma expands

   ⇒ Direct conversion to electricity



Artist's animation of the Fusion Engine



Magnetohydrodynamic simulation of the Fusion Engine

Regulatory Strategy

Key to regulator: Onsite limit of 100Ci of T
Regulation equivalent to hospital

1. **International Pilot**
   - Fusion export is easy
   - Build here, test there. EU, Asia.
2. **D-He3 NRC USA**
   - 2 yr funding initiation (2014)
   - 2 yr review program
   - Initial licensing
     - Prototype
     - 2-4 yr licensing