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World Fusion Outlook

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International Announcements in Fusion

Global

- Speaking at COP28, US Special Envoy for Climate Change, John Kerry, announced an international engagement plan to advance fusion, saying the technology will become vital in the energy transition:
  - "Fusion energy is no longer just a science experiment."
  - "There is potential in fusion to revolutionise our world."
  - "We are edging ever-closer to a fusion-powered reality. And at the same time, yes, significant scientific and engineering challenges exist"

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International Announcements in Fusion

Global

- A COP28 panel titled "Fusion and Climate: The Conversation Continues" highlighted the current momentum in the field of fusion. With DG Rafael Mariano Grossi, Christofer Mowry (Chairman of FIA and CEO of Type One Energy) and Laban Coblentz (ITER)—was indicative of the growing consensus that increased private/public partnership in fusion is the way to move forward. The panellists discussed how this could be broadened and expanded through the IAEA's announced World Fusion Energy Group and other initiatives.

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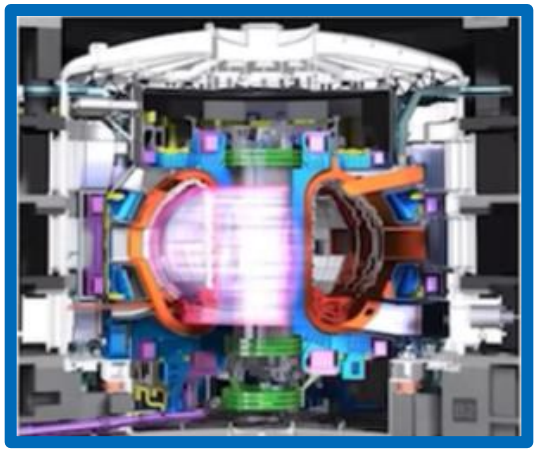
Why Fusion Now?

Market Conditions Becoming Attractive for Fusion

Market pull

Climate emergency very high in public consciousness

Public



https://www.iter.org/mach/tokamak

Technical demonstration

ITER and DEMO will demonstrate the low field path to fusion…

2 Paths to Fusion

Complimentary to one another

Lessons Learned on ITER have led to private investment

Private

Private investment

>$6.2 Bn invested and committed in 43+ Start-Ups (FIA 2023)

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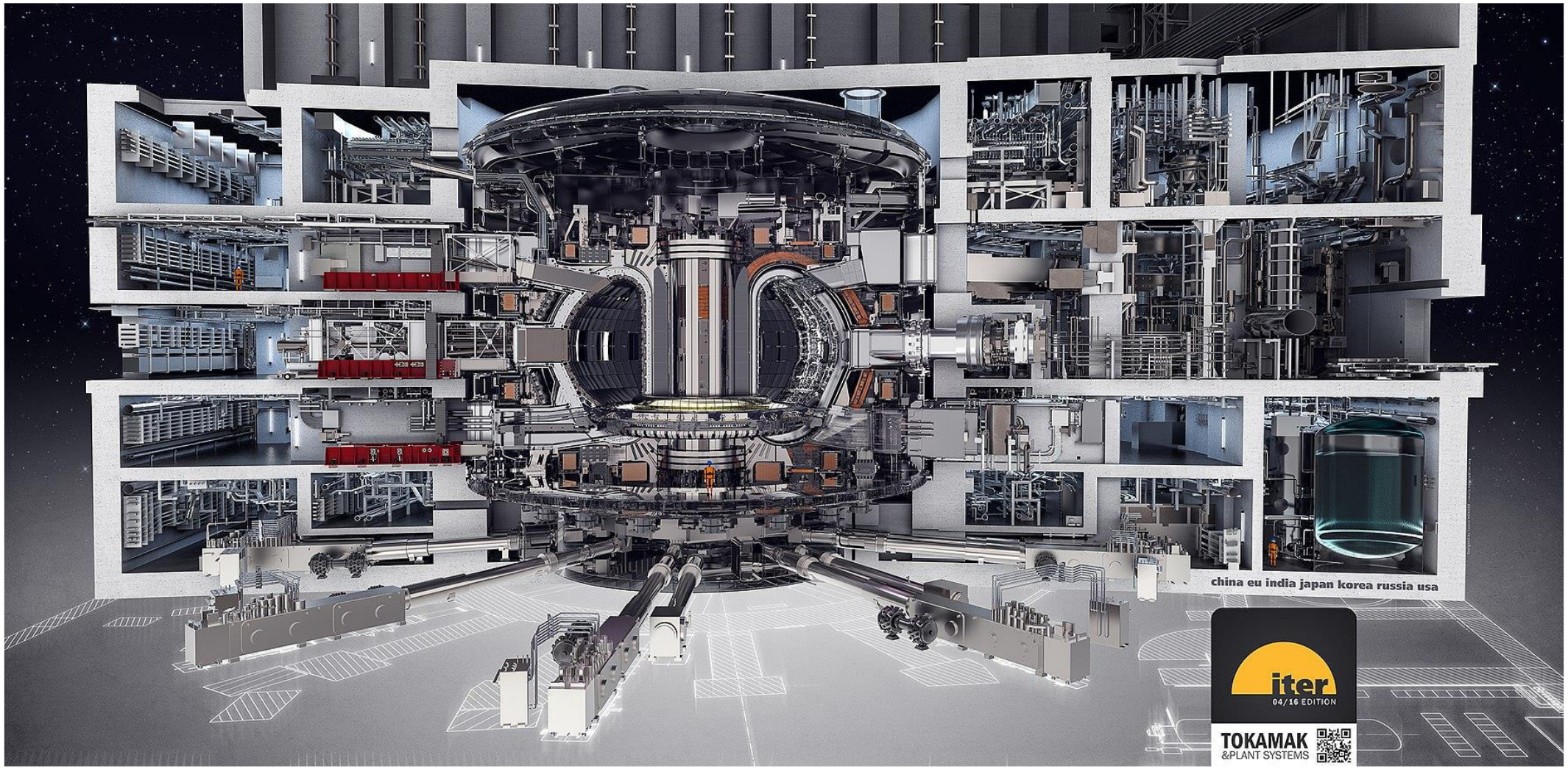
The ITER Tokamak – Magnetic Confinement (D-T Fuel)



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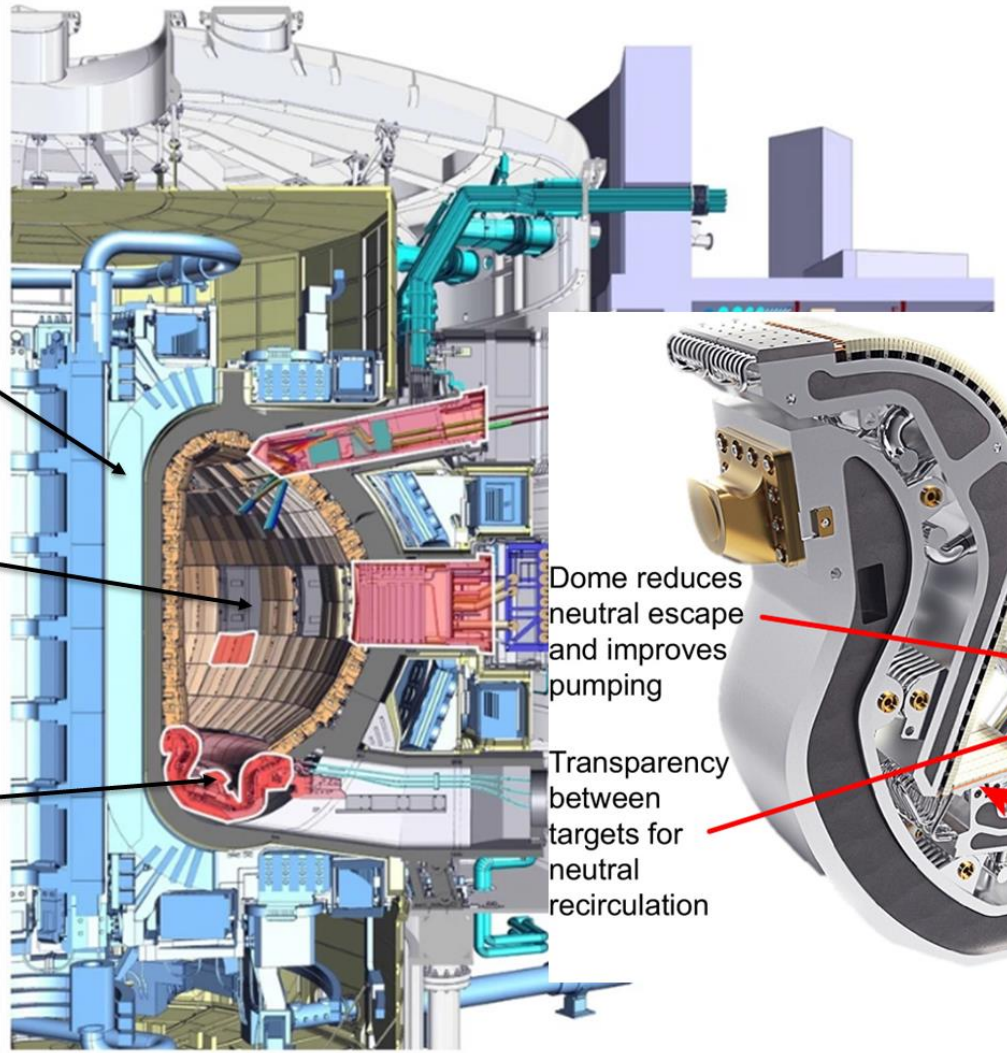
The ITER Tokamak – Magnetic Confinement (D-T Fuel)

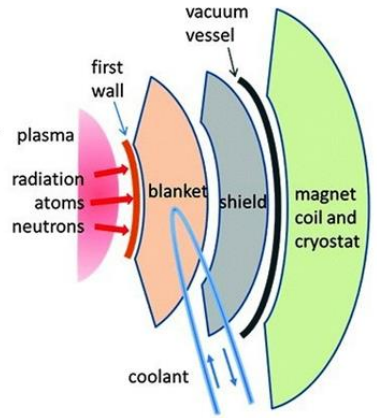
Temperature Range
-270˚ to 150M˚C

TF Coils @ -270˚C

Plasma @ 150M˚C

PFCs @ 500 - 800˚C
W melts @ 3422˚C

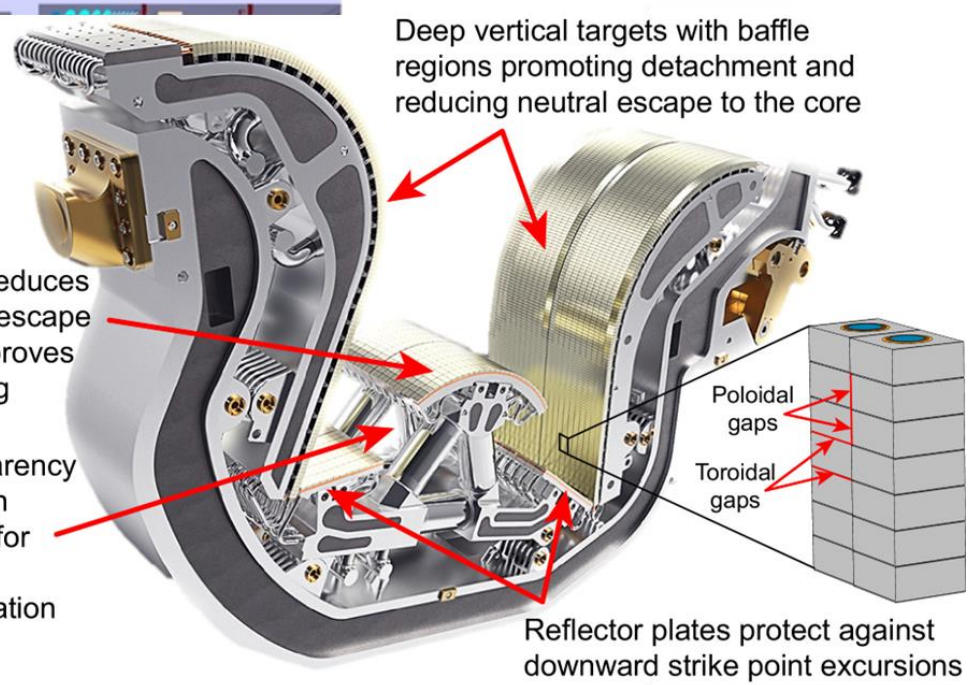




Deep vertical targets with baffle regions promoting detachment and reducing neutral escape to the core

Dome reduces neutral escape and improves pumping

Transparency between targets for neutral recirculation



Reflector plates protect against downward strike point excursions

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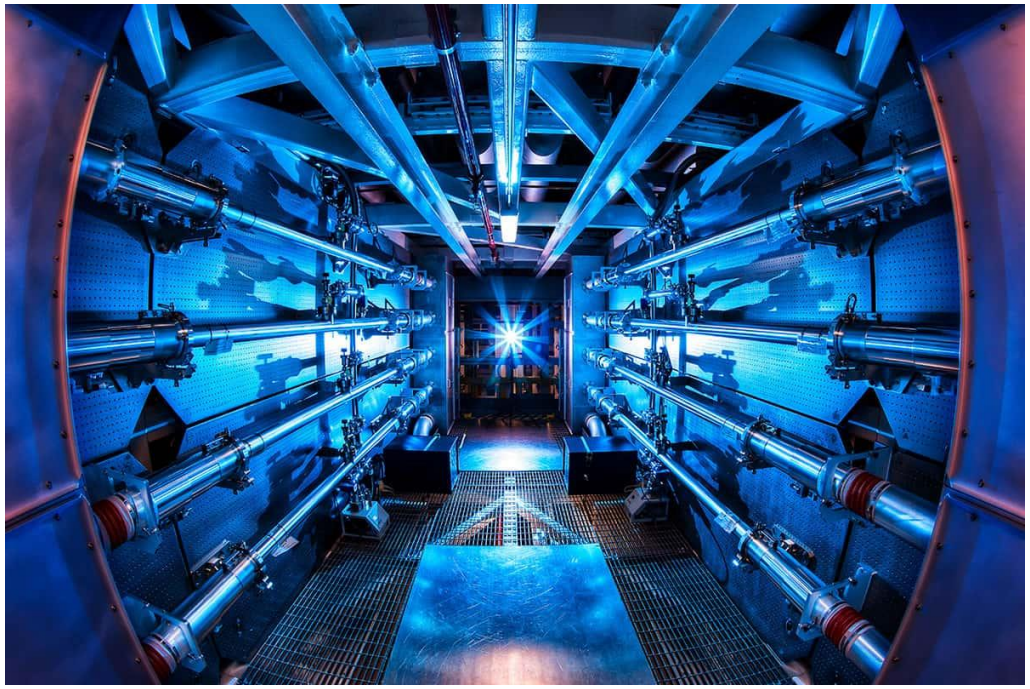
National Ignition Facility (LLNL) – Inertial Fusion (D-T)



Q>1 on 5 December 2022

[Feds confirm historic fusion ignition at Lawrence Livermore National Laboratory - CBS San Francisco (cbsnews.com)]

[Breakthrough in nuclear fusion energy announced - BBC News]

[US scientists reach long-awaited nuclear fusion breakthrough, source says | CNN Politics]

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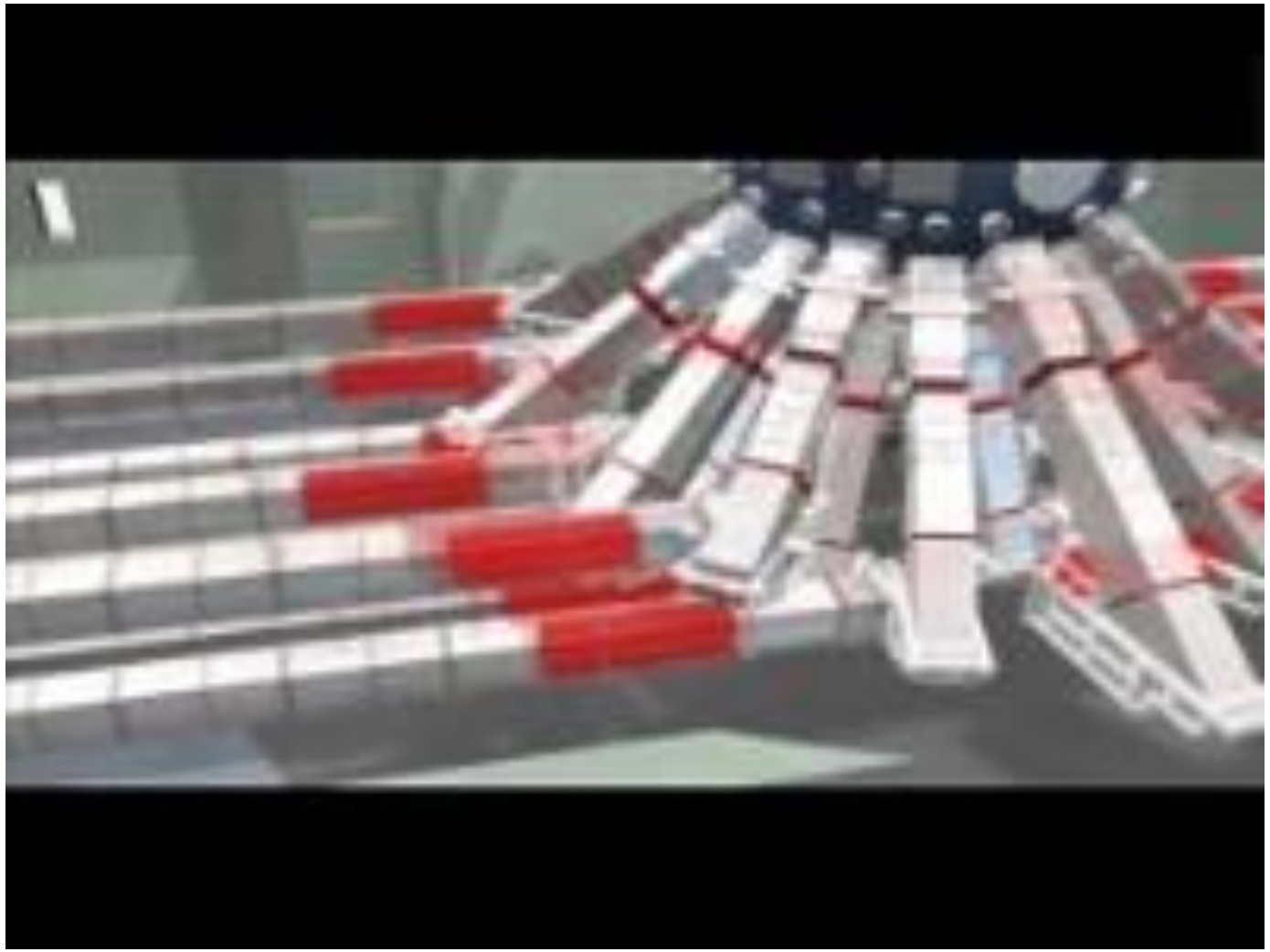
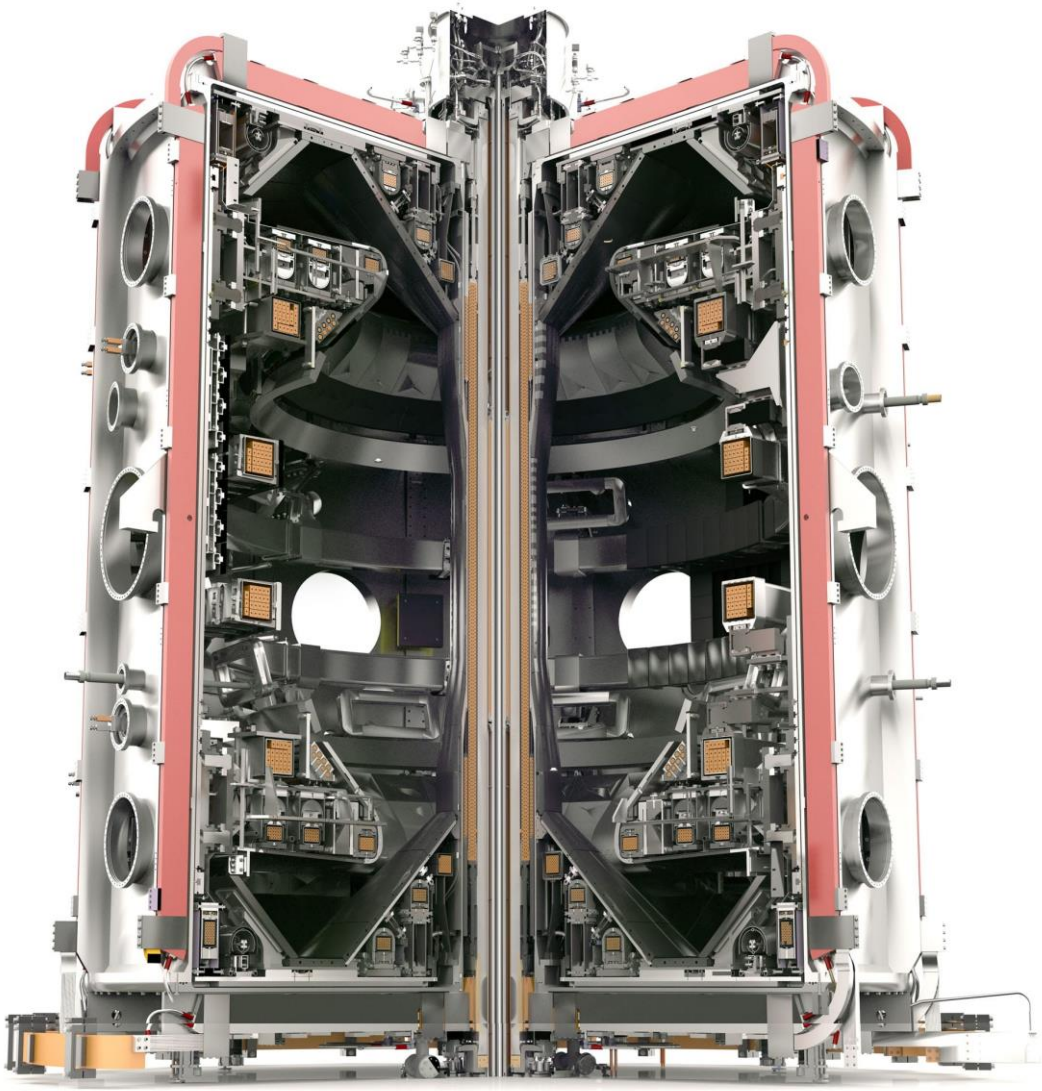
How it works.



UKAEA Spherical Tokamak for Energy Production (STEP)



October 2022, UKAEA announced site selection in West Burton at a retired coal plant, site prep is underway

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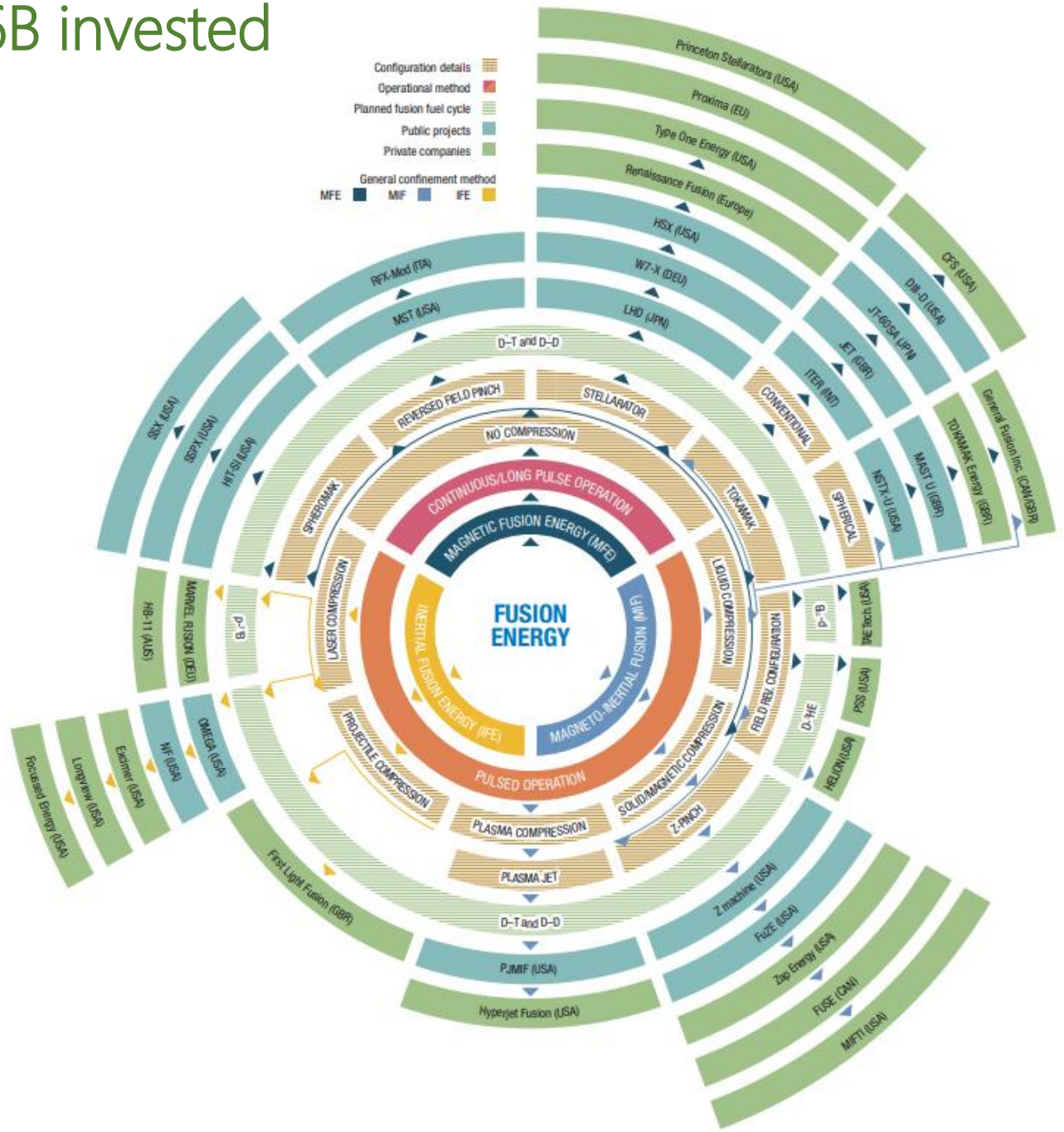
Commercial Fusion – over $6B invested

Commercial Fusion – over $6B invested

As the number of devices in development and/or construction increase, so is the need for IAEA involvement

The international fusion community will need to come together both public and private to make fusion a reality

Diagram from: WFO23



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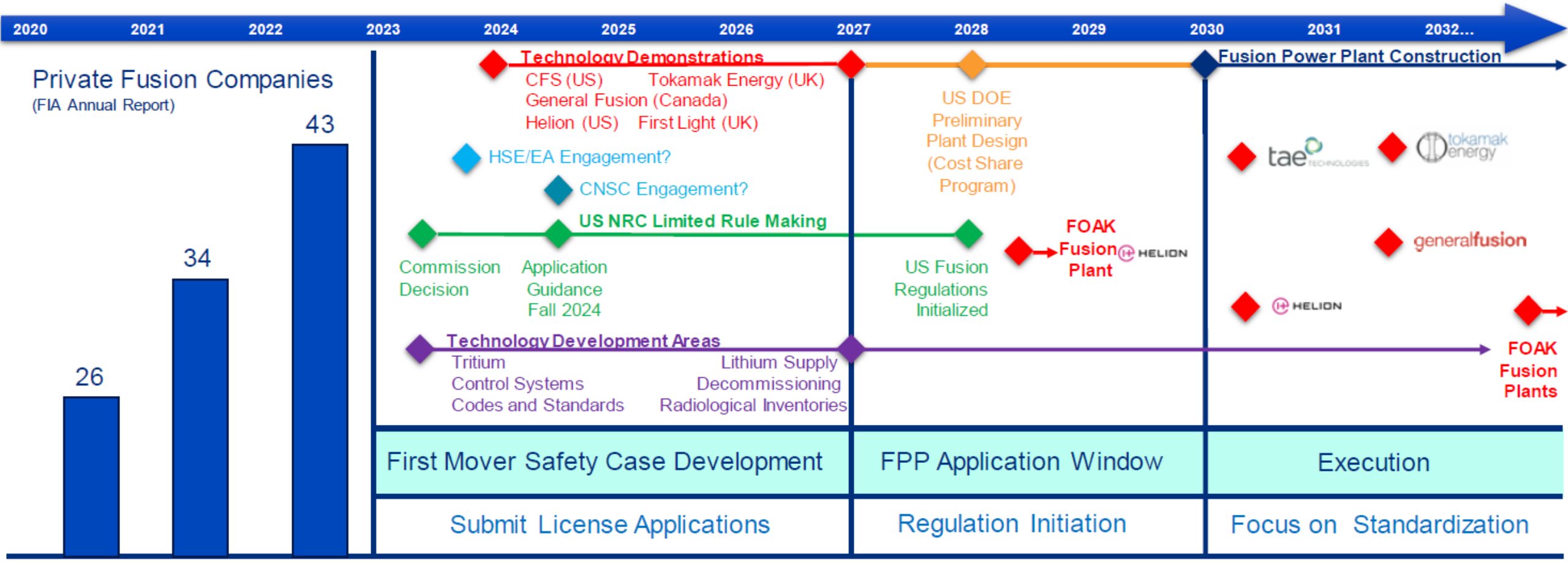
Commercial Fusion – Landscape 2023 and Outlook

Diagram courtesy of Sehila Gonzalez at the Clean Air Task Force



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Commonwealth Fusion Systems – Tokamak Magnetic Confinement (D-T)

The SPARC Tokamak

The ARC Tokamak
How it works…

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Commonwealth Fusion Systems – SPARC Construction

Devens Concept
~June 2020

[Italy's Eni and CFS speed up plans for fusion energy]

[Commonwealth Fusion Systems Selected by U.S. DOE for Milestone Program to Accelerate Commercial Fusion Energy]

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Start of Construction in June 2021
Devens Reality
Pictured - 27 October 2023

Helion Energy - Reversed Field Configuration

Magneto-Inertial Fusion (D-He^3 Fuel)

Everett Washington

27 July 2021

[Microsoft agrees to buy electricity generated from Sam Altman-backed fusion company Helion in 2028]

[Nucor and Helion to Develop Historic 500 MW Fusion Power Plant (prnewswire.com)]

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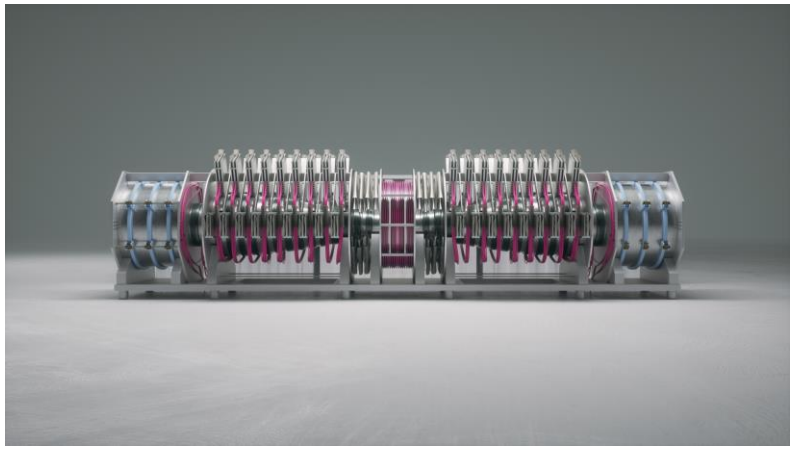
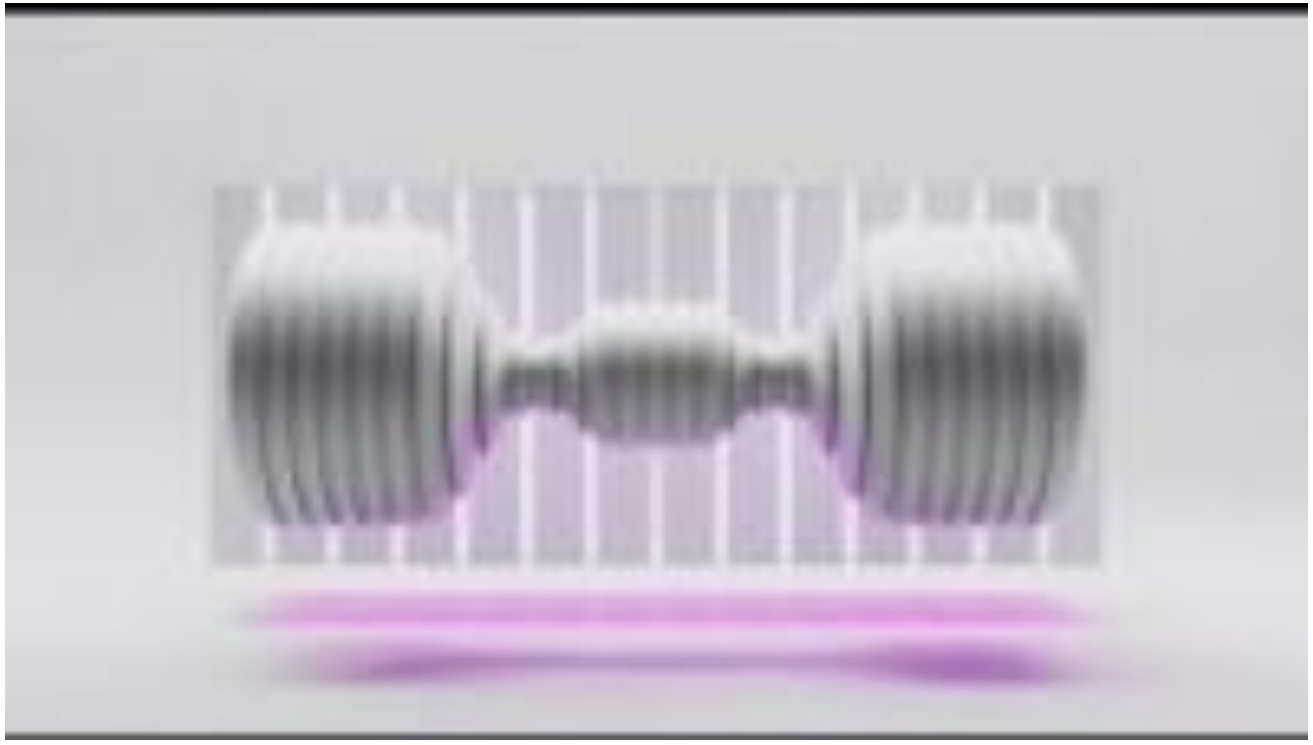
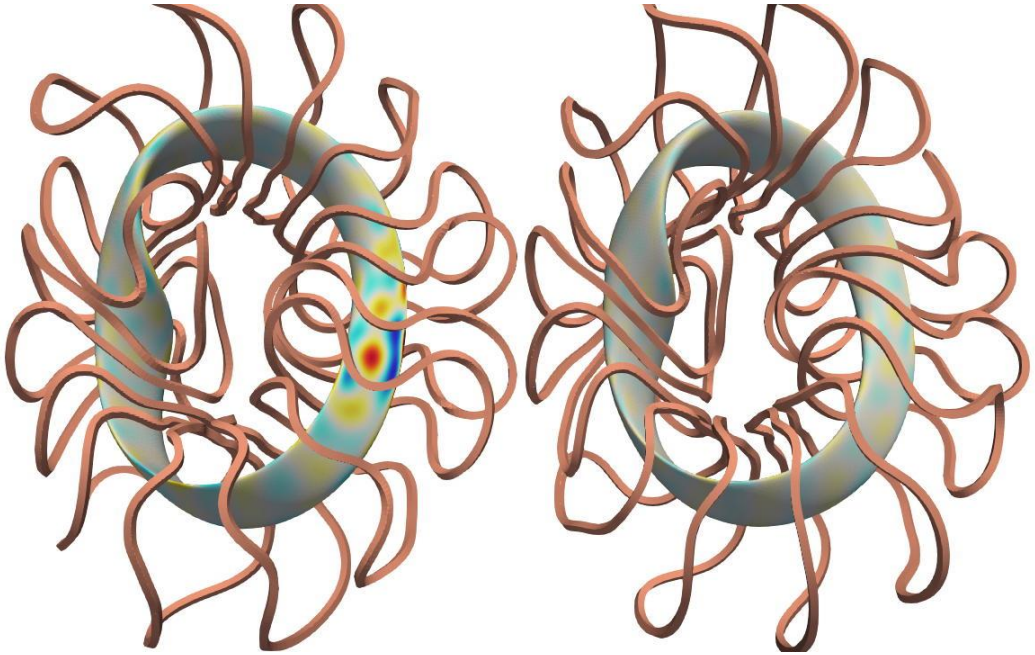


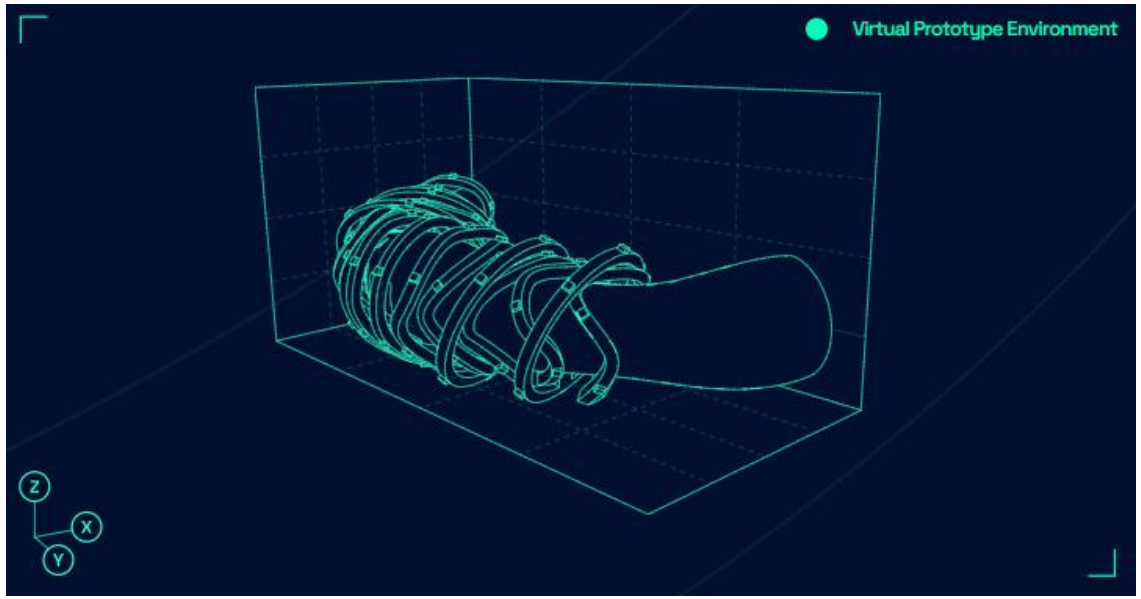
How it works.



Proxima Fusion – Quasi-Isodynamic Stellarator (D-T)

[Proxima Fusion starts cooperation with other startups – Munich Startup (munich-startup.de)]





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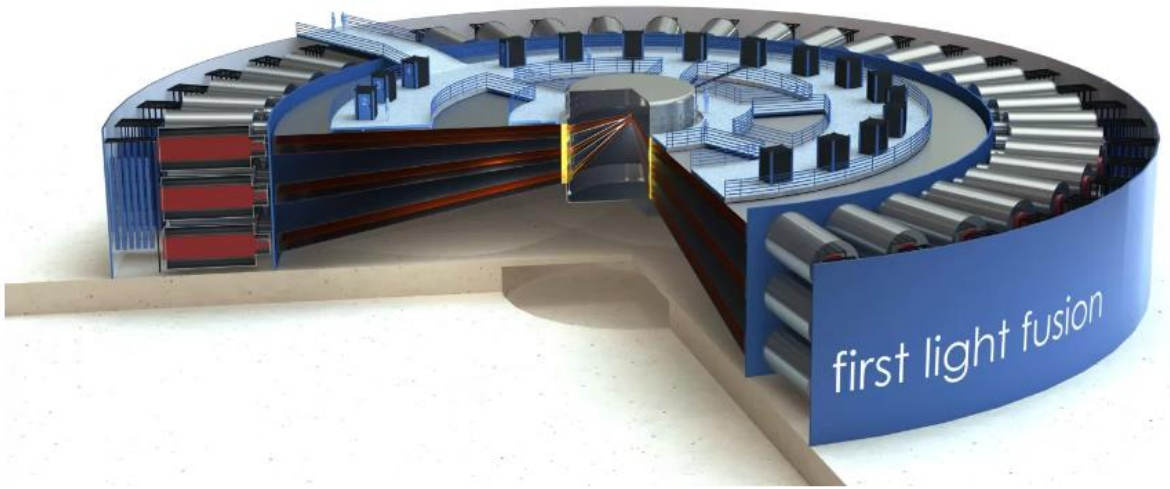
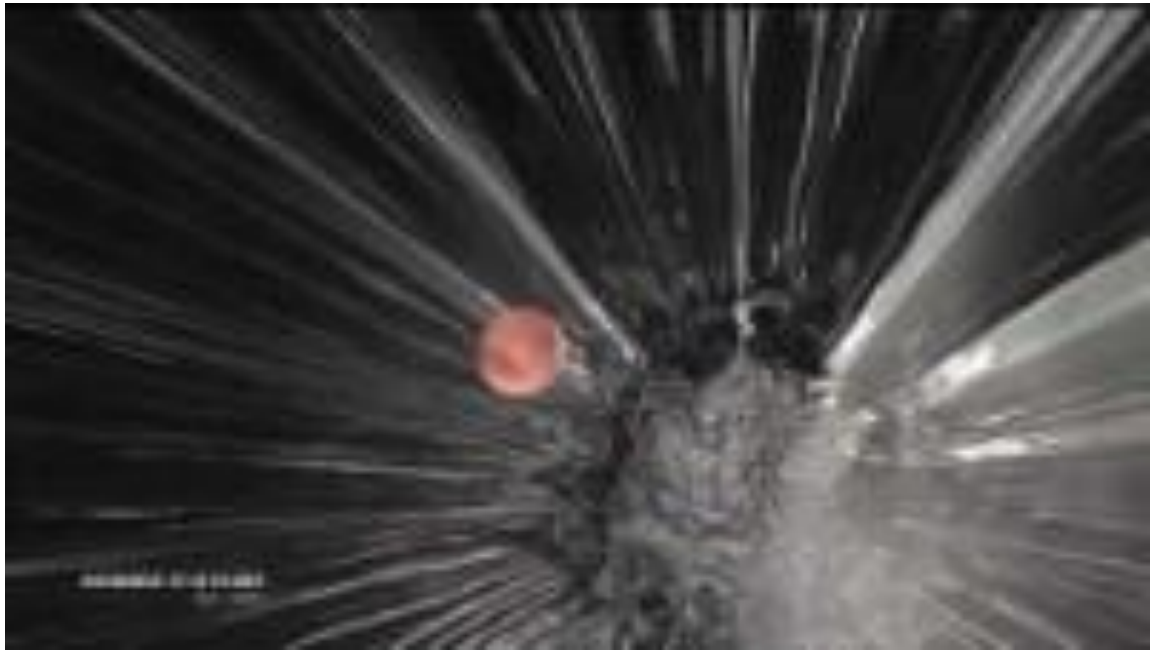
Other Approaches

FIRST LIGHT FUSION (Projectile Fusion)

[First Light reactor concept – YouTube]
[Projectile fusion – YouTube]





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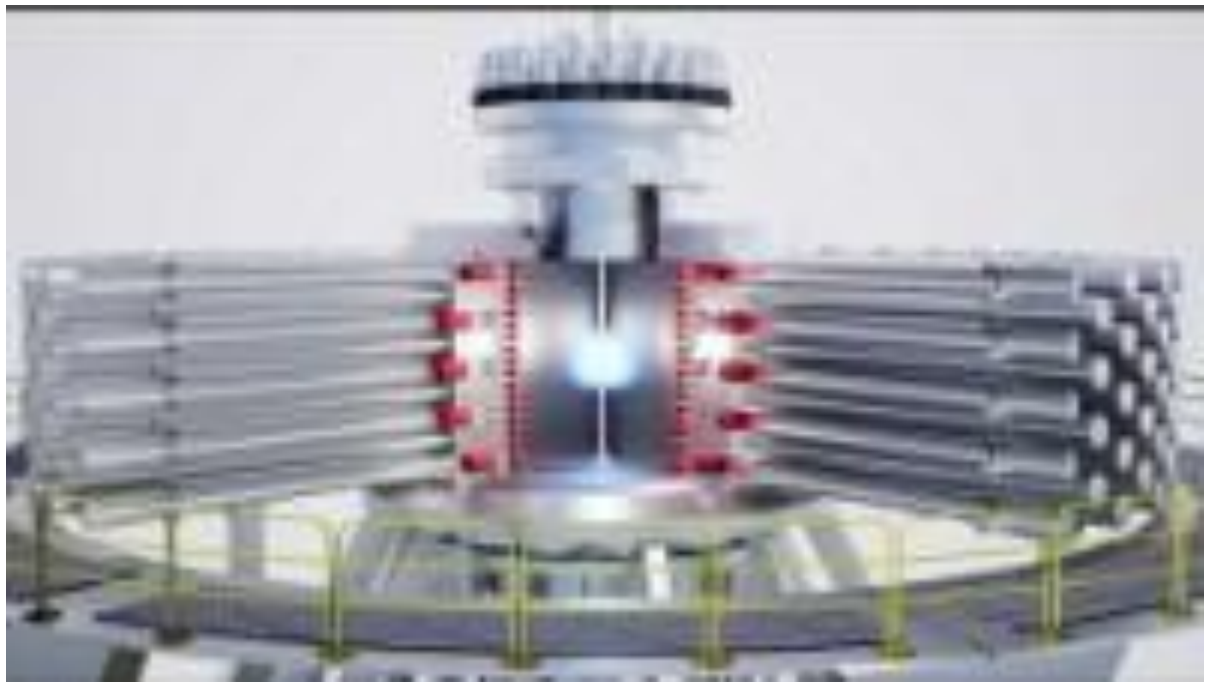
Other Approaches

General Fusion: Magnetized Target Fusion

Technology - YouTube



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Fusion Energy Conference 2023

Fusion announcements from the IAEA DG Grossi

- During the Fusion Energy Conference 2023 in London, DG Grossi made several announcements

World Fusion Energy Group

- A new IAEA event, the World Fusion Energy Group; bringing together scientists and engineers, policymakers, financiers, regulators and civil society as the "next leg of the fusion energy journey will get us from experiment to demonstration to commercial fusion energy production"

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Fusion Energy Conference 2023

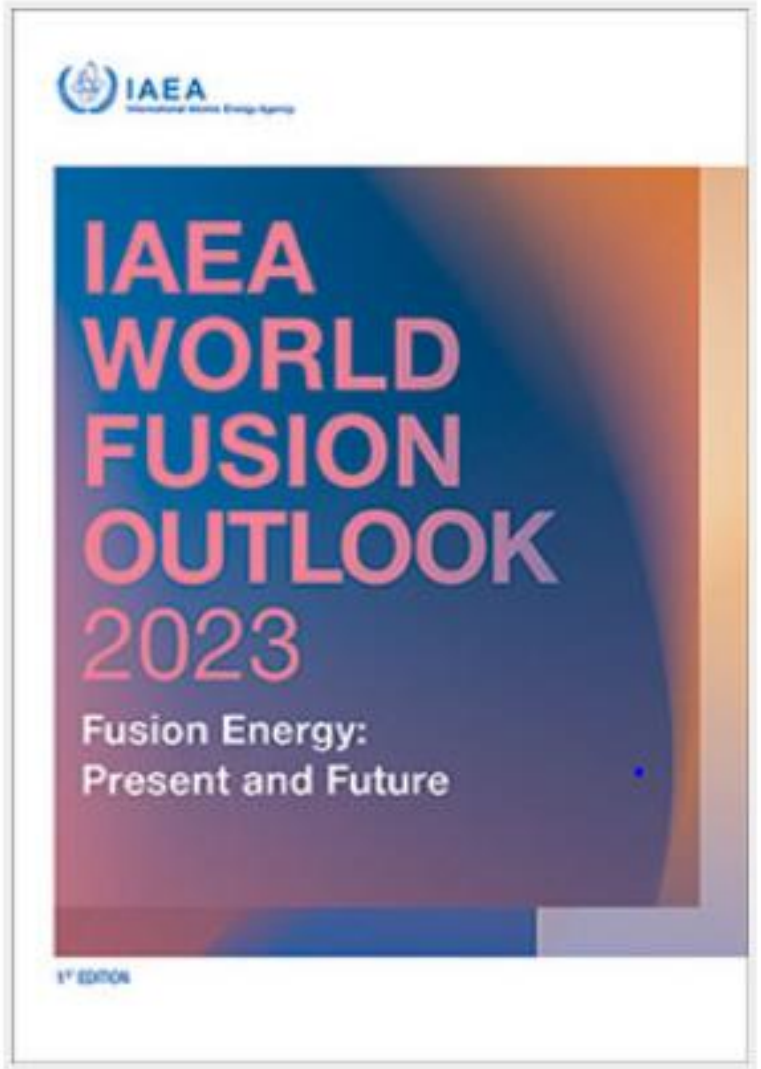
Fusion announcements from the IAEA DG Grossi

World Fusion Outlook

- Intended it to be a regular publication providing "authoritative information and updates on fusion energy"
- and to become "a global reference for energy R&D, technology development and prospective deployment of fusion as a source of unlimited low carbon energy"
- World Fusion Outlook

Fusion Key Elements

- "shortly invite fusion experts to work with the IAEA to outline Fusion Key Elements such as fusion-related definitions, characteristics and criteria for fusion energy to help develop common understanding among stakeholders essential for global deployment"



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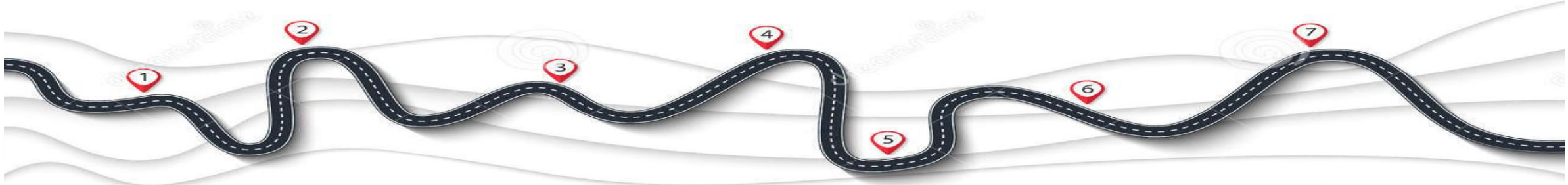
Fusion Energy Development and Deployment Framework

Topics include (not exhaustive):

- *Fusion Key Elements* (announced by DG Grossi at FEC2023)
- Guidelines for Fusion Safety Assessments and Regulatory Frameworks
- General Design Criteria and Applicable Codes and Standards
- Legal and Institutional Considerations
- Fusion Hazard and Safety Analysis
- Technologies and Fuel Cycles
- Fusion Economies and Financial Analysis
- Modelling and Simulation (neutronics, digital twins, etc.)
- Materials and Structures
- Knowledge Management (engineering, integration, construction LLs)
- Stakeholder Engagement
- Energy Justice and Social Licensing
- Program Development and Deployment
- Systems Integration and Construction
- Staffing and Training, Operations and Maintenance Requirements
- Fusion Power Plant Capacity and Integration with Grid (infrastructure)



Fusion Energy Development and Deployment Framework

The need for a fusion framework

- Purpose is to provide subject modules to assist member states in developing national fusion programs
- Web-based training will be provided for each module
- All framework modules will be managed in the Fusion CONNECT platform; international collaboration is essential to build out the framework

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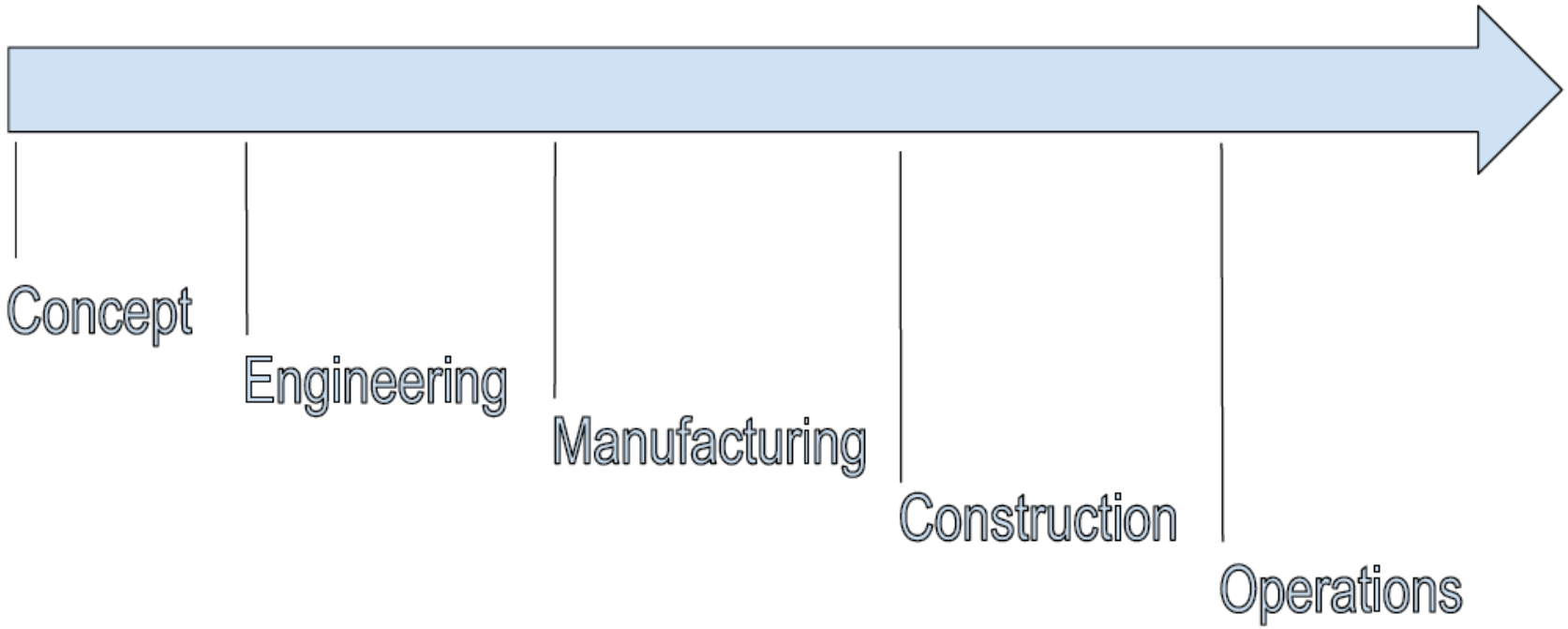
Challenges in realizing commercial fusion…

Putting the challenging physics conditions required in a successful fusion demonstration aside – as have been discussed this week…

The following slides contain a few examples of additional institutional, legal, engineering and project challenges we need to overcome.

Stages of Fusion Project Development:

Concept → Engineering → Manufacturing → Construction and Installation → Mechanical Completion → Integration → Commissioning → Integrated Commissioning → Operations → Upgrades and Modifications → Operations → Decommissioning

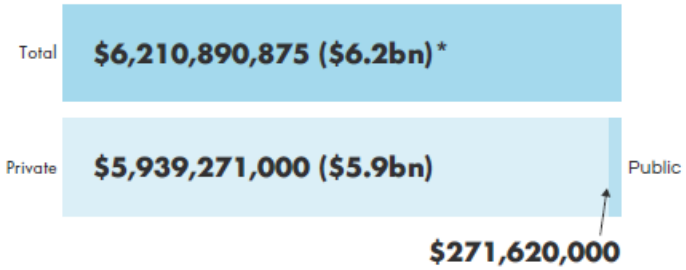


Funding

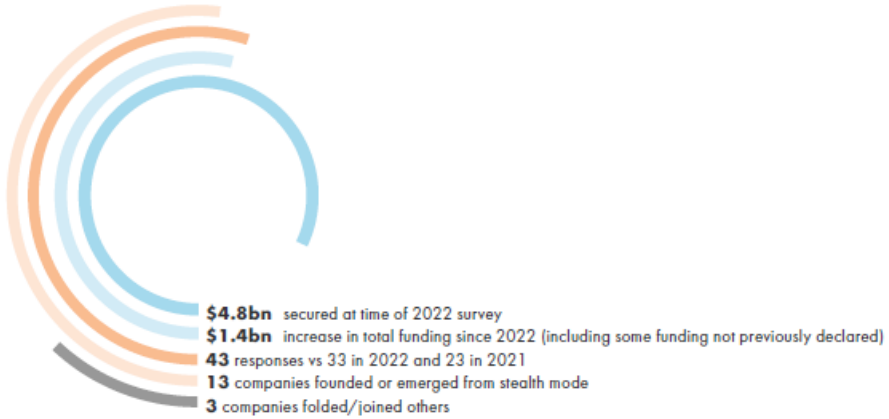
Private funding survey from FIA 2023 report:

HIGHLIGHTS TO DATE

1. Funding for fusion companies

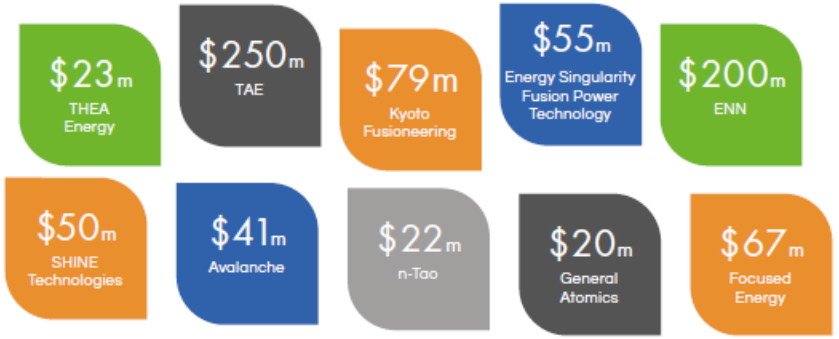


2. Change since 2022 survey

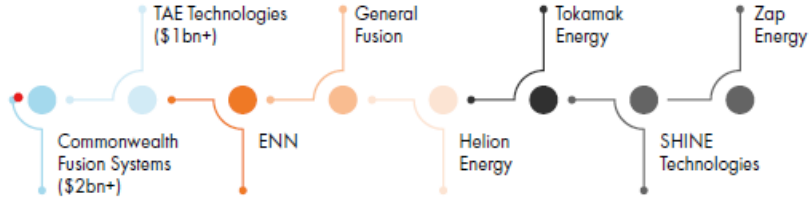


* Some figures have been rounded. Some funding was declared privately, hence total figure here is higher than combined figures stated in company profiles.

3. Notable investments since the last survey



4. Companies with $200m investment or more



5. Location

By primary HQ

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International Announcements in Fusion

UK Atomic Energy Authority

Federal Ministry of Education and Research

United Kingdom

- Confirmed that all planned prototype fusion energy facilities in the UK will continue to be regulated by the Environmental Agency & Health and Safety Executive, unlike fission power plants which are regulated by the Office of Nuclear Regulation
- The UK announced the Fusion Futures Programme, with GBP650M over 5 years
- Includes: 2200 training places, fuel cycle testing facility, infrastructure for private fusion

Germany

- Federal Ministry of Education and Research announced 1B + 370M euro by 2028

Japan

- Adopted its first-ever national strategy on fusion, highlighting the need to create a domestic industry in the field, with wider participation of the private sector
- Working on guidelines for fusion technology regulation

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内閣府 Cabinet Office

Creation of Harmonious Diversity

QST National Institutes for Quantum Science and Technology

International Announcements in Fusion

United States

- Department of Energy announced $46M for the first 18 months to 8 companies advancing designs and R&D as part of Milestone-Based Fusion Development Program
- 7 December 2023: DOE announces $42M for inertial fusion energy hubs
- The US NRC announced its separation of fusion from fission and regulate near-term fusion energy systems under the by-product material framework (accelerators, etc.)
- California in 2023, was the first state to recognize fusion energy as a separate and distinct technology from nuclear fission

United Kingdom and United States

- The UK Department for Energy Security and Net Zero and the US Department of Energy announced a new strategic partnership to accelerate the demonstration and commercialization of fusion energy

U.S. DEPARTMENT OF ENERGY | Office of Science

UK Atomic Energy Authority

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