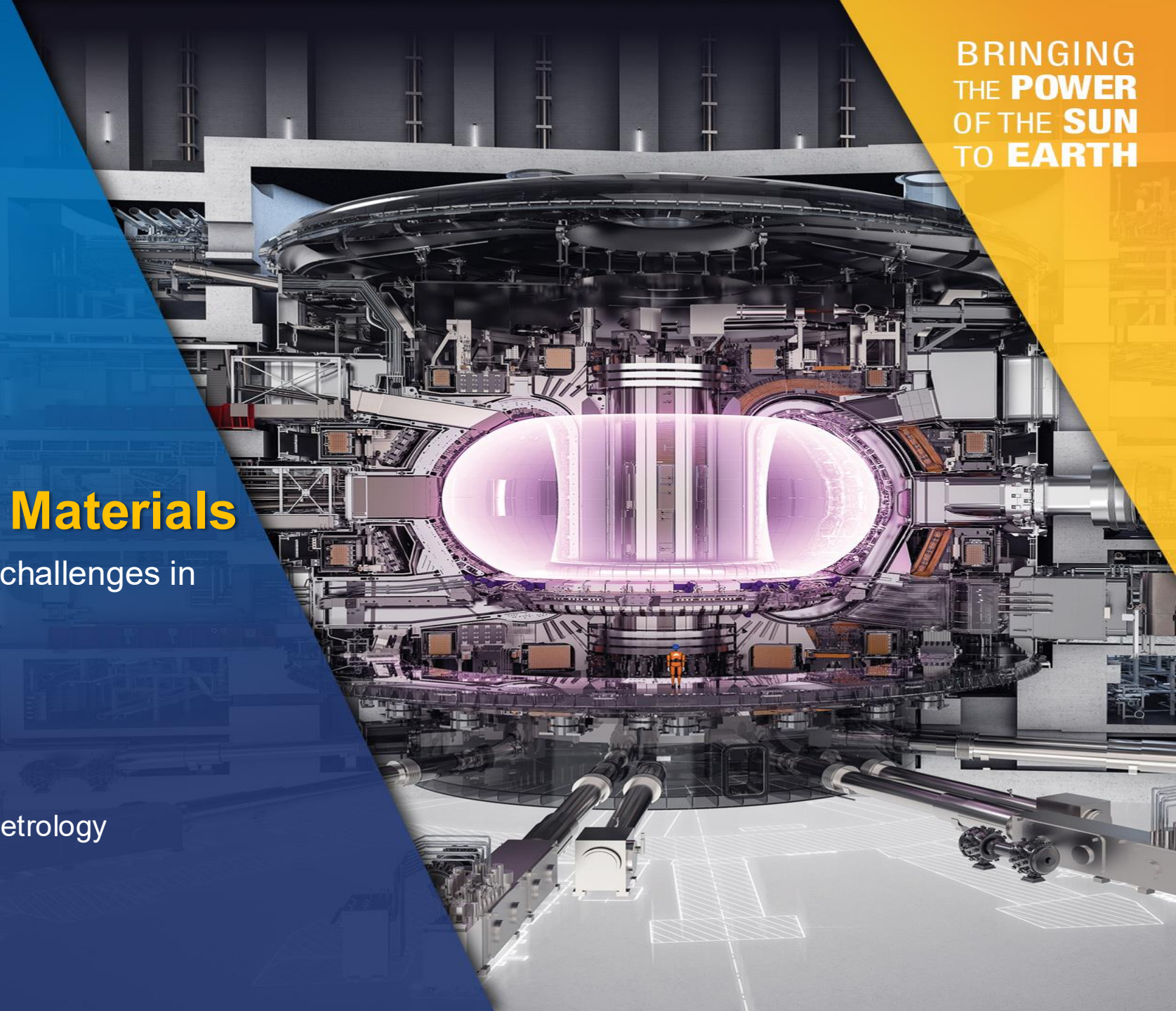
FUSION FOR ENERGY

BRINGING THE POWER OF THE SUN TO EARTH



Challenges with Fusion Materials

Critical materials technology gaps and challenges in constructing fusion power plants

Stefan Wikman

Head of Materials, Manufacturing & Metrology

The European Joint Undertaking for ITER & the Development of Fusion - Fusion for Energy (F4E)

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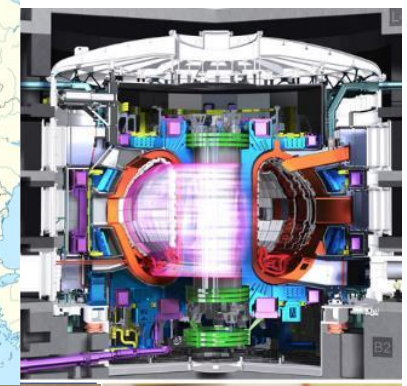
- **F4E is EU Joint Undertaking based in Barcelona Offices also in Cadarache & Garching (Munich)**
- Staff: ~465 (core is team of engineers and project managers)
- Budget: €5.6 billion 2021-2027

(628 M€ via F4E contracts as of 2025)

Spent €6.6 billion 2007-2020

F4E is responsible to deliver Europe's contribution to ITER (about 50% of the budget)

European Commission



Reflection: Rapid global growth in nuclear energy sector

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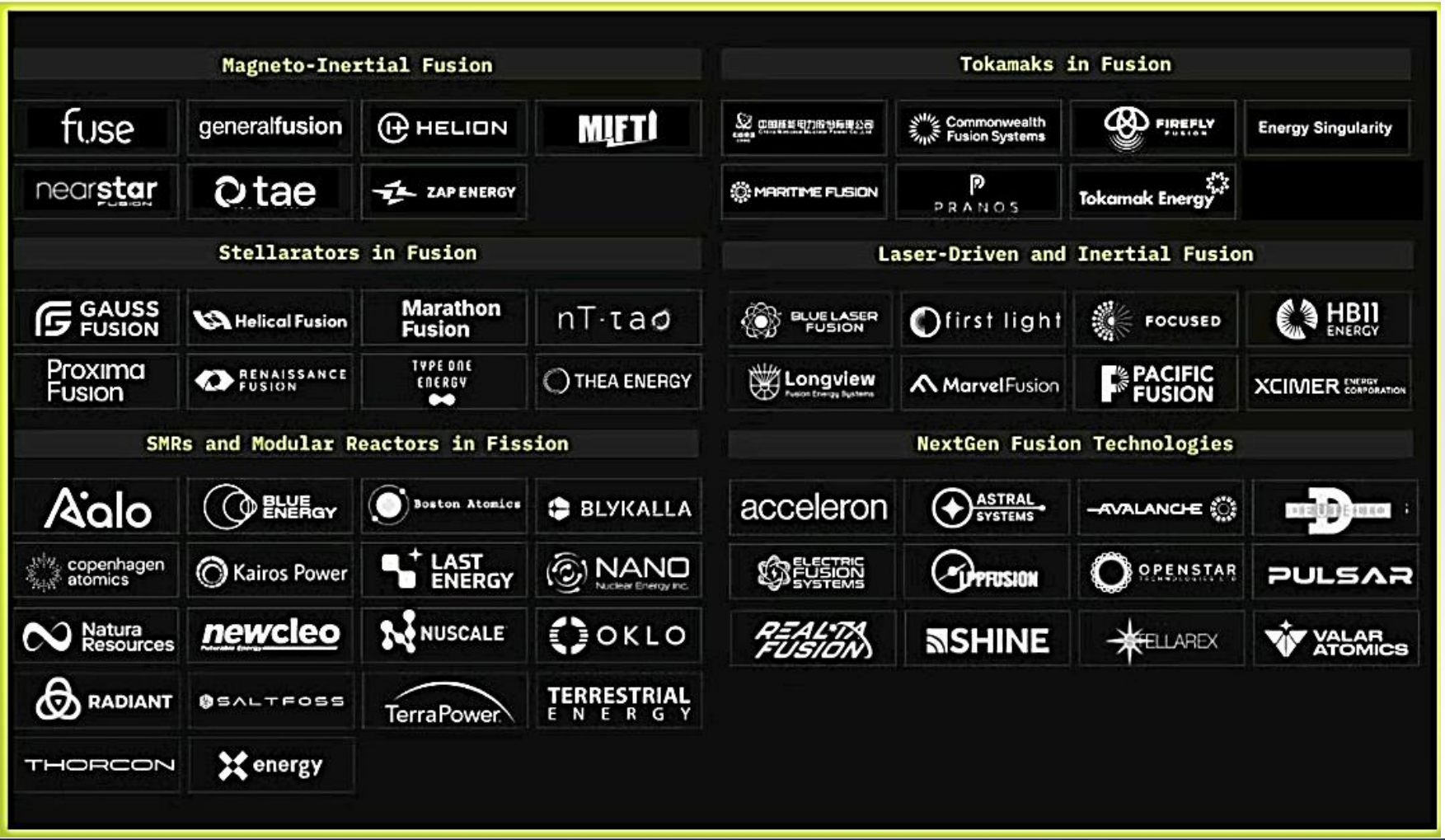
The Fusion & Fission Startups Map *(by ClimateHack)*



Caught in LinkedIn “flow”

60+ startups

Fusion for Energy (F4E) – Our Strategic Vision

FUSION FOR ENERGY

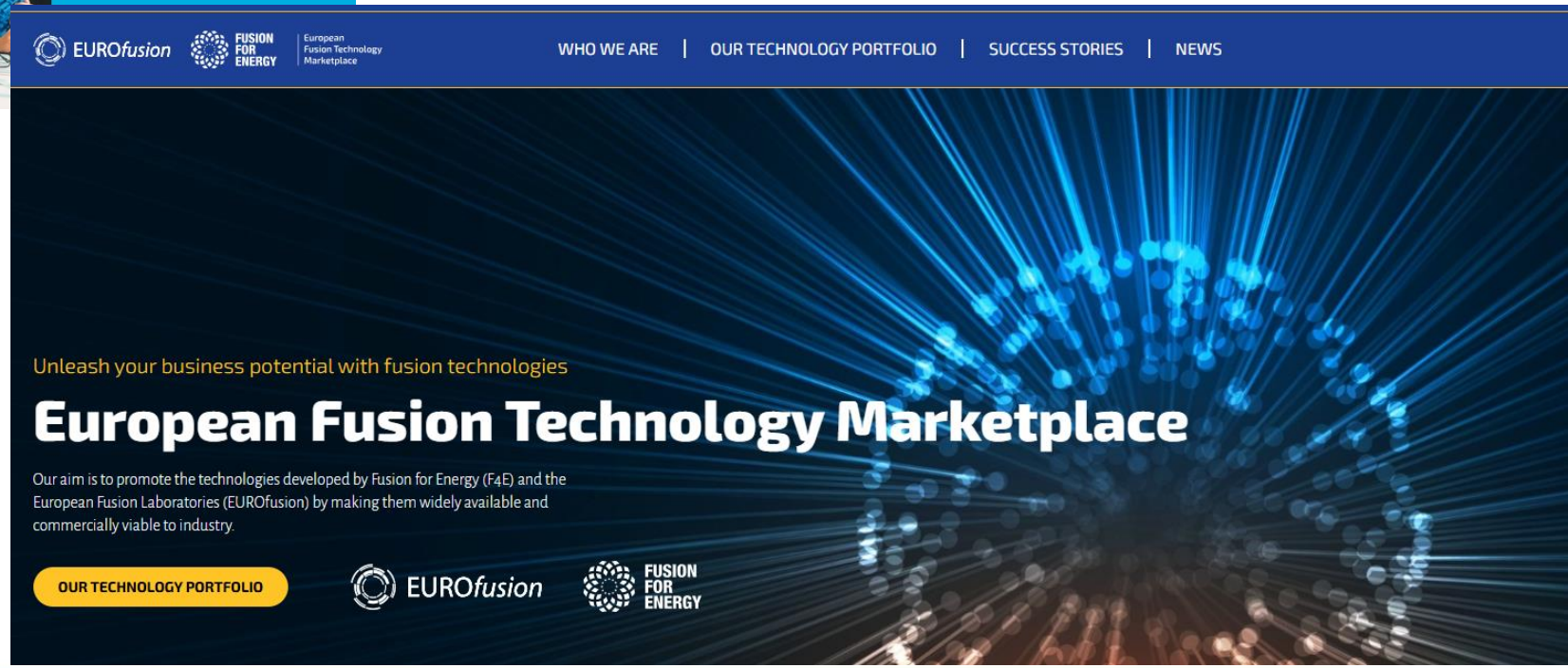
We develop talent and knowledge for the future fusion power plants in Europe

F4E Strategic Vision: Looking to the future

We focus on the construction and operation of ITER and other fusion projects

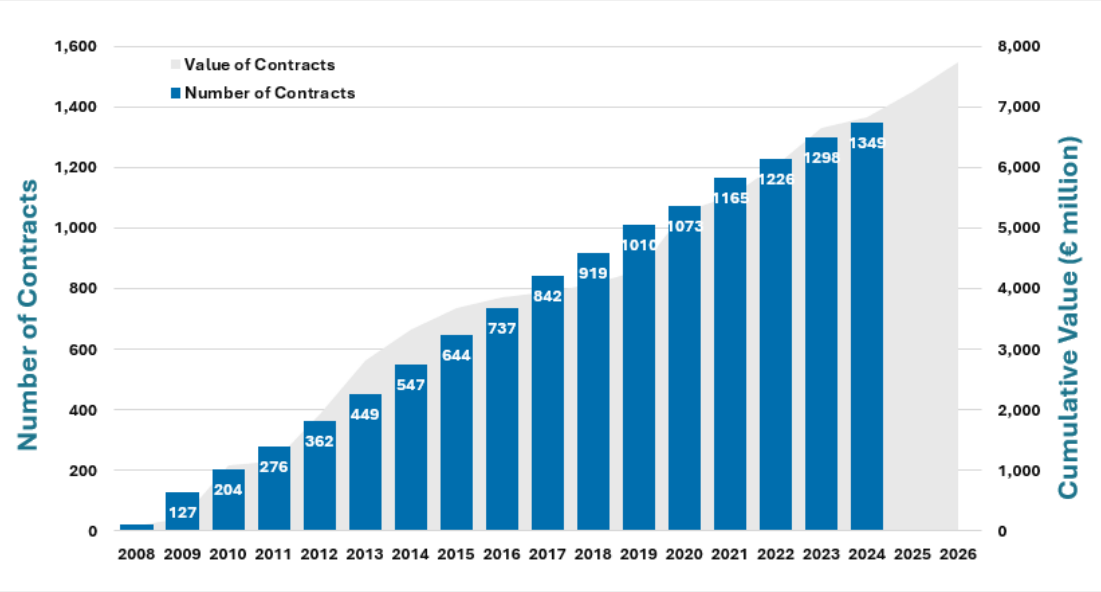
We help create a competitive European Fusion Industry

Our ambition => Platform of the EU Fusion Supply Chain



We have invested >7B€ in EU Supply Chain for ITER

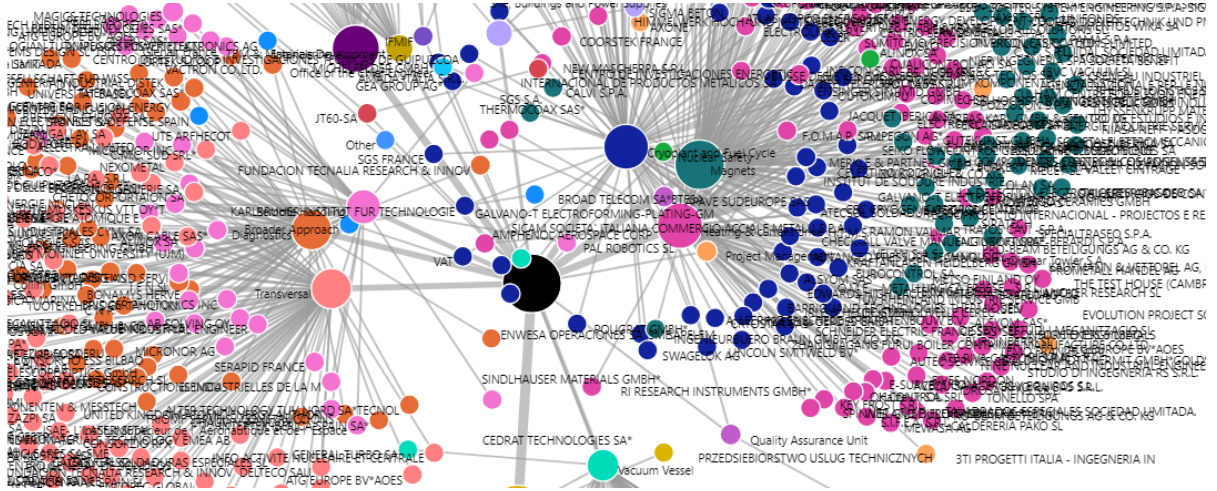
(And mapped the supply chains along the way)



- Over €7bn of procurement
- >1200 contracts
- >2100 subcontractors
- >700 industries
- >75 research organisations

- 2350 Companies mapped
- 796 Main contractors
- 200+ Technologies mapped
- 23 EU Countries

… and growing



We work on several fusion projects

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Broader Approach
Three projects with **Japan**
JT-60SA close to First Plasma

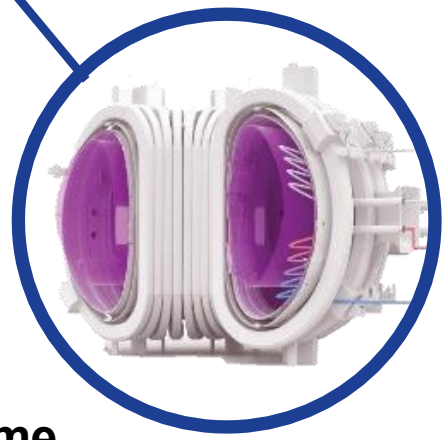
ITER
Europe's contribution to ITER
Procurement need examples

Short Term | **Medium Term** | **Long Term**

IFMIF-DONES
Early phase of design & construction
of **D**EMO **O**rientated **NE**utron **S**ource

Jose Aguilar 11th March

DEMO
Early design studies by EUROfusion
DEmonstration **F**usion **R**eactor
F4E to lead future construction



Technology Development Programme

Technology Development Programme Joint Mapping Exercise

FUSION FOR ENERGY

Main organisers

FUSION FOR ENERGY

EUROfusion

Critical partners

GO4FUSION

European Fusion Association

CERN

Participating Companies

ANI Agência Nacional de Inovação · a.r.u. Anglia Ruskin University · CDTI · cea · ENEA · European Commission · Fraunhofer · Università di Genova · HUN REN · ICSI · iter · KIT Karlsruhe Institute of Technology · University of Ljubljana · Lund University · Max Planck Institute for Plasma Physics · University of Stuttgart · TU/e Eindhoven University of Technology · UK Atomic Energy Authority · VTT

Absolut System · Groupe ADF · Air Liquide · ALSYMEX · amentum · ATG europe · ATKINS · BIMO Tech · boccard · EFusion · CHART · CURIUM · DG SKID · EIFFAGE · EKIUM · eni · EQUANS · ESTEYCO · extract Technology · Focused Energy · GAUSS FUSION · Freemelt · LSA Space · JACOMEX · KINECTRICS · Kraftanlagen · KYOCERA · Kyoto Fusioneering · M2CG · MIRION · Monteiro · nuvia · orano · research instruments · saes · sener · sgenia · SIMIC Spa · SULZER · tecnalia · Tekniker

Neutral Beam Cryopumps (2x3 units, cat D Item Range: 4 000 000 - 12 000 000 EUR

- 500 cryopanels, >650 thermal shield panels
- Tight tolerances

Target CFT Q2 2026 (early May).

Mitica cryopump prototype

Neutral Beam Magnetic Shielding

- S235 Carbon Steel thick plates with low impurities (Cobalt, Tantalium, Nobium) => 1000 tons.

Pure Iron plates

OMF-1183: 6 Ports Manufacturing & Assembly +Testing Facility. **Cat. D**

Framework Contract with 3 specific contracts:

1. Material and Tooling Supply
2. Ports Manufacturing
   - Special SS-316 LN IG Supply
   - Manuf. of the ports
   - Manuf. of water, gas, and electrical feedthroughs
   - **Boron Carbide (B4C) and Glass to metal**
   - Integration, assembly
3. Installation/Operation of Test Facilities.

Under evaluation => for subcontracting

Some Recent Highlights

European Factories in Motion for ITER First Wall Panels

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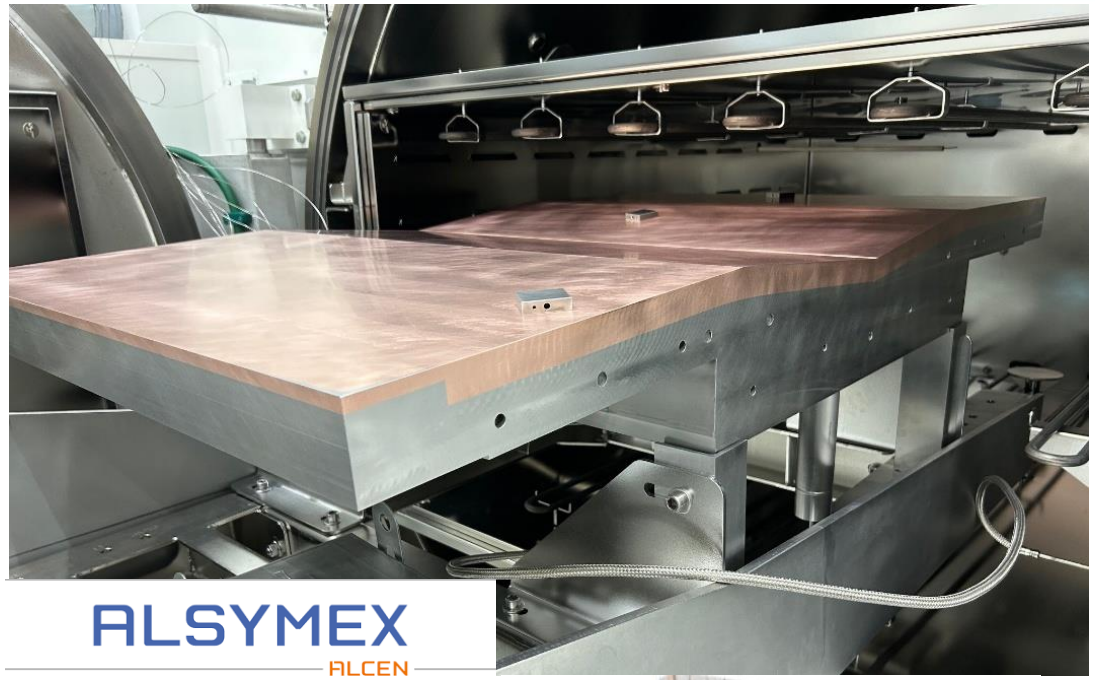
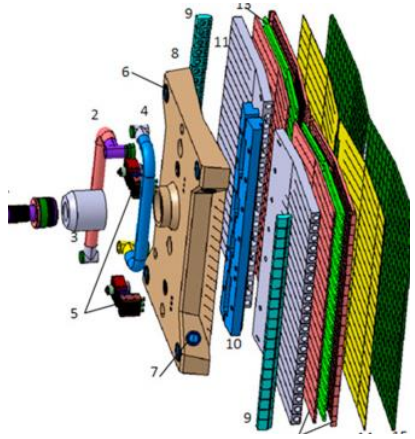
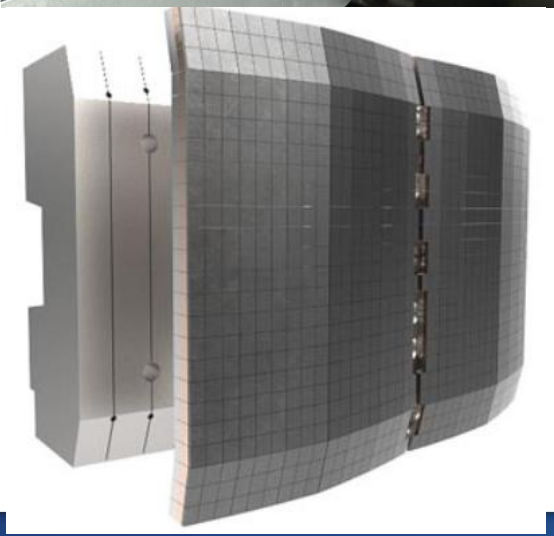


ALSYMEX
ALCEN





Tungsten Procurement still to be done

In the future such mechanical components likely made via Additive Manufacturing AM

Specific challenges with plasma facing armour

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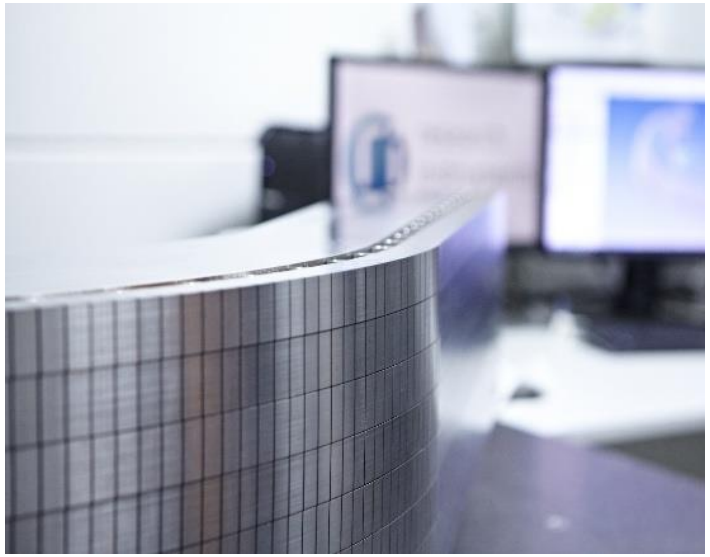
Geo-political situation with Tungsten

Rapidly increasing raw materials cost

Few raw material suppliers (changing)

ITER: about 1 million W-tiles for the First Wall alone (75.000 kg W)
(when other fusion start-ups follow, can market keep up?)



Technology gaps to fill

Cost efficient manufacturing of Tungsten (new era with Additive Manufacturing)

New pure Tungsten variants need qualification and “power lift” to higher TRL levels

Public Funding needed to support inclusion in standards

Specific Challenges with plasma facing armour

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Additive Manufacturing is bound to have a strong impact on materials and design development

Plasma Facing Armor

- Develop W-alloys
- Develop alternatives to W
- Thermal Stress Resisting Joints
- Joining of Dissimilar Materials

Alloying W with other elements.
W-Ni-Fe, W-Cu and more.

In parallel next steps in F4E vision:

Develop Tungsten alloys (low TRL)

Develop alternative materials (low TRL)

Develop efficient shield coatings (low TRL)

Tungsten fiber reinforced tungsten (W/W composites?) low TRL

Turn concepts into actions to develop materials needed to harness the power of the sun

Contracts ongoing (Freemelt, Fraunhofer and RHP) for new W grades with Gradient Joints

Tender evaluation ongoing for cost efficient AM of Tungsten

Specific challenges with fusion materials

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Heat Sink Materials

CuCrZr is ITER baseline, but not so corrosion resistant

Alternatives to CuCrZr

- Depends on coolant media
- Manufacturability

Plasma Facing Components

Manufacturing Parameters for AM
Component Design for AM
Simplify Manufacturing
Assembly of components

Challenge areas to advance TRL levels

Copper-alloys, CuCrZr	Challenges
Commercial precipitation hardened CuCrZr grade with stable materials properties after repeated heating above 1000 °C (for example, to join surfaces of CuCrZr to stainless steel requires ≥1040 °C via Hot Isostatic Pressing). Dispersion strengthened, ODS copper. Alternative Cu-alloys.	Fluctuations in materials properties and chaotic grain growth is a common issue with precipitation hardened CuCrZr. ODS copper needs development and testing for comparison with precipitation hardened CuCrZr. Alternative Cu-alloys as graphene reinforced copper to be developed and tested. Joining of Cu-alloys to low activation steels.

Tender evaluation ongoing for graphene reinforced copper

Specific challenges with structural materials

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Challenge areas to advance TRL levels

Materials topic	Challenges
Oxide Dispersion Strengthened (ODS) steels Reduced Activation Ferritic Martensitic (RAFM) steels Reduced Activation Bainitic (RAB) steels Vanadium alloys SiCf/SiC Emerging materials	Supply chain to manufacture batches. Powder and wire for Additive Manufacturing to lower cost of mock-up development and qualification. Effects of strong magnetic fields (accumulation of corrosion products). He and H driven embrittlement. Radiation effects

Overview of what materials are available today and where are the gaps.

Liquid Metal Armor	Challenges
Sn, Pb, Li, Bi, CD, PbSn, LiPb, SnLi concepts. Develop mock-ups with liquid metals for assessment (for example W structure with liquid Sn).	Map transmutation generated activated isotopes. Corrosion rates. Compatibility with structural materials. May need development of protective coatings.

Vision for new projects

Creating EU Fusion Materials Roadmap

The main objectives of this workshop are to:

•Identify R&D opportunities for future fusion reactors,

•Facilitate the exchange of knowledge,

•Foster collaboration and partnerships,

• Setting priorities for funding.

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Technology Development Programme

—

Advanced Fusion Materials Workshop

5-7 May 2026, Lund

This workshop, **hosted by Big Science Sweden and the European Spallation Source (ESS)**, will be the founding event to create a European community for Advanced Fusion Materials.

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Thank you
for your attention

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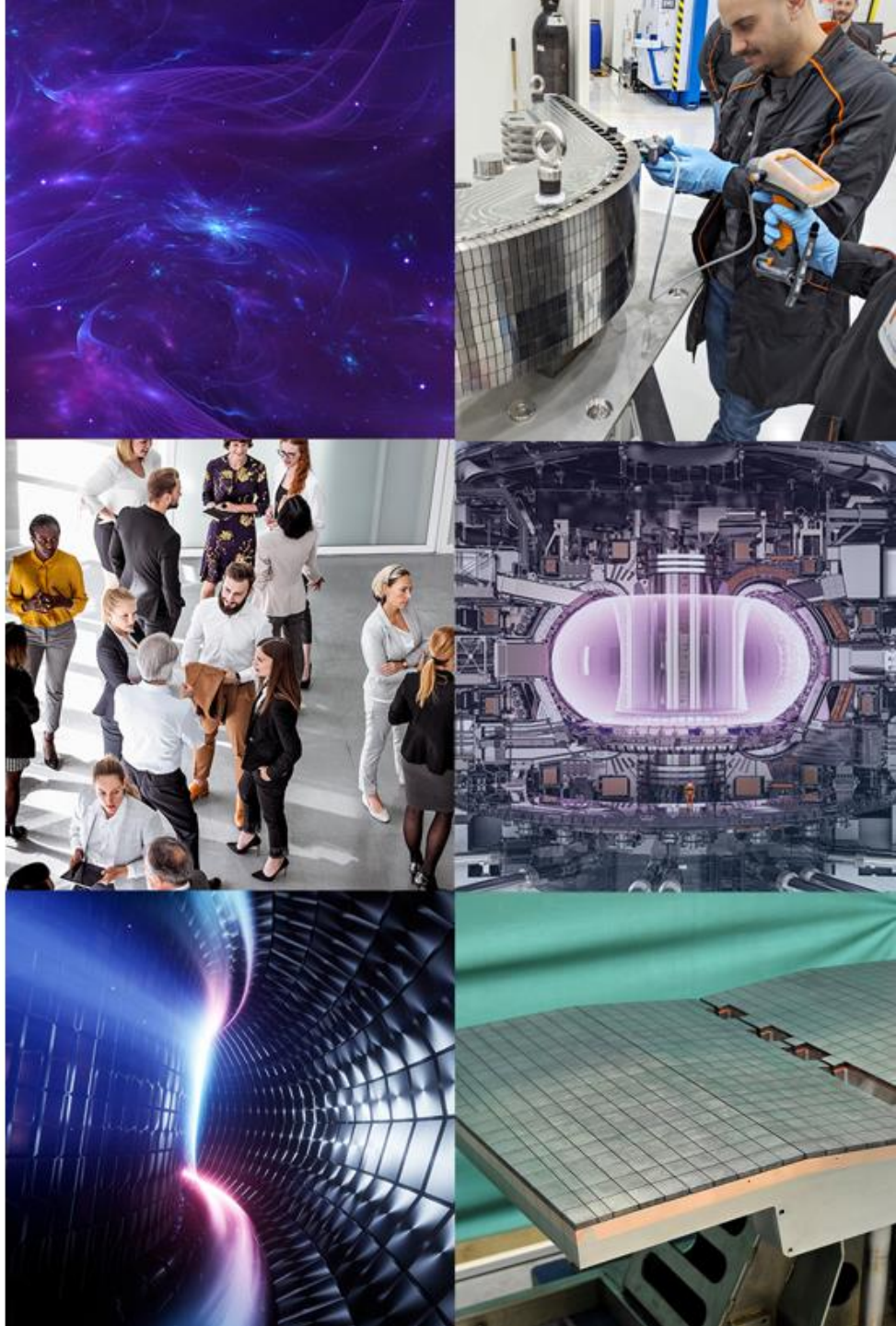

Materials design for operational conditions - Challenges
Influence of neutrons, particles and thermal shocks

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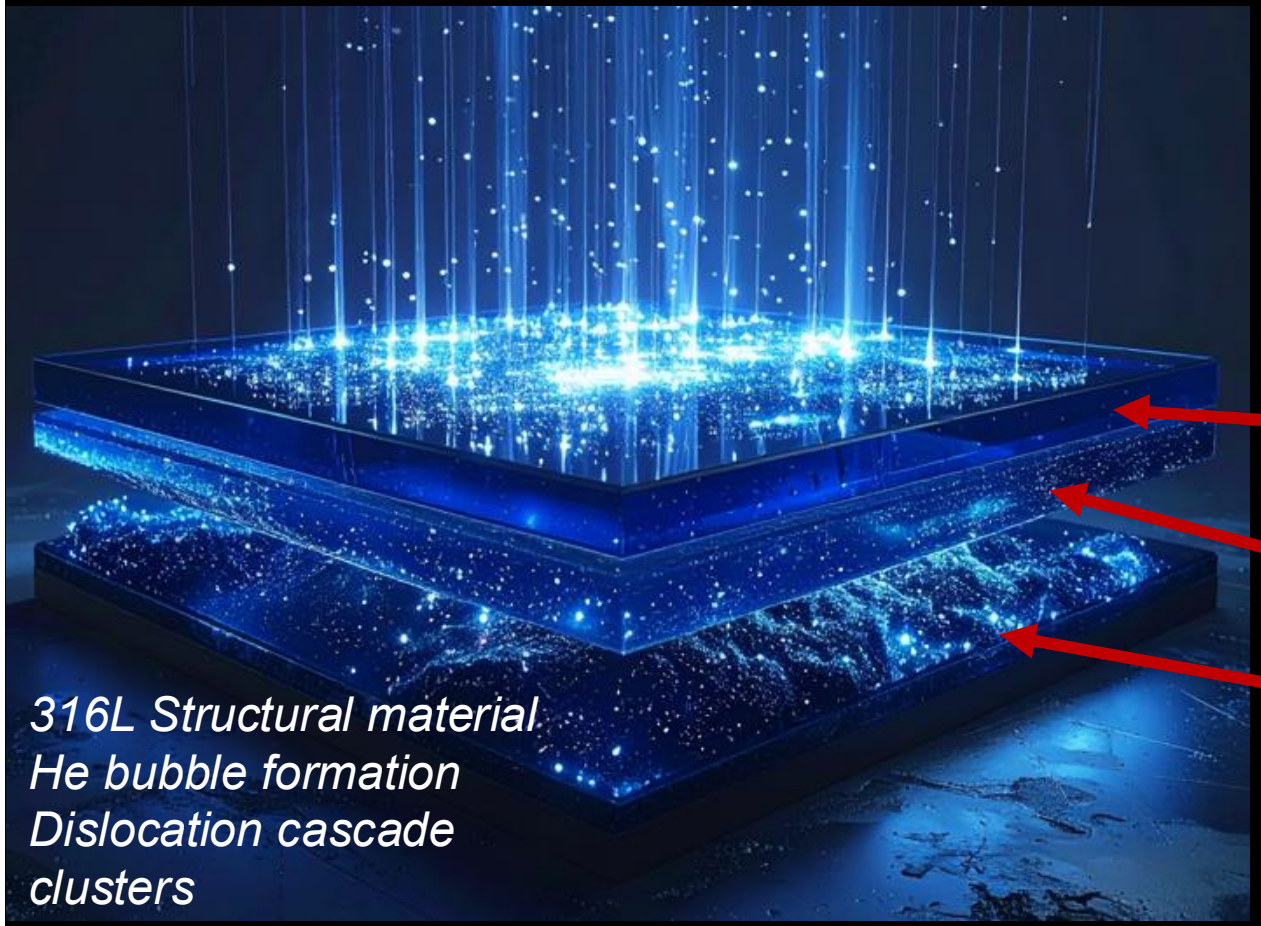
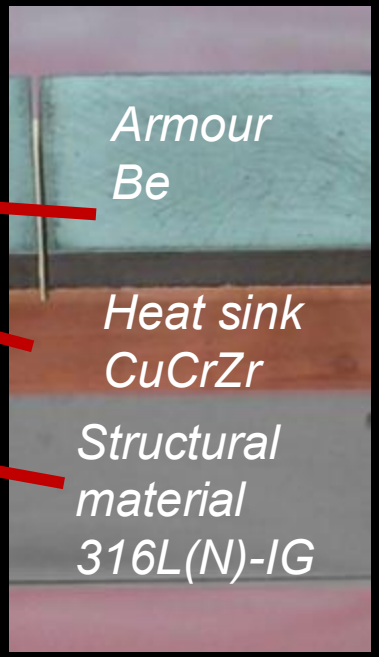
First Wall Design

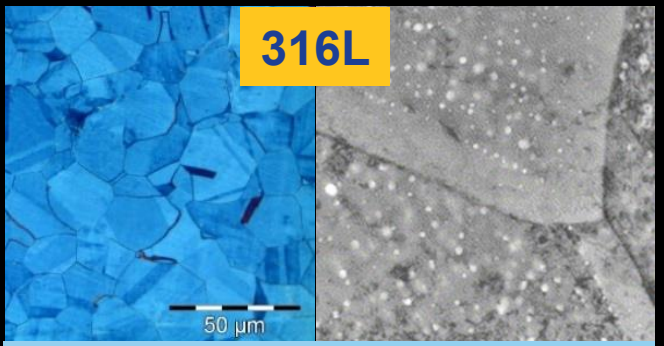
High energy particles passing through 3 layers of First Wall materials



Armor, optimum reflect heat & let neutron pass (Be in image)
Today with W (more armour dislocations)



Today
Tungsten replaced Be

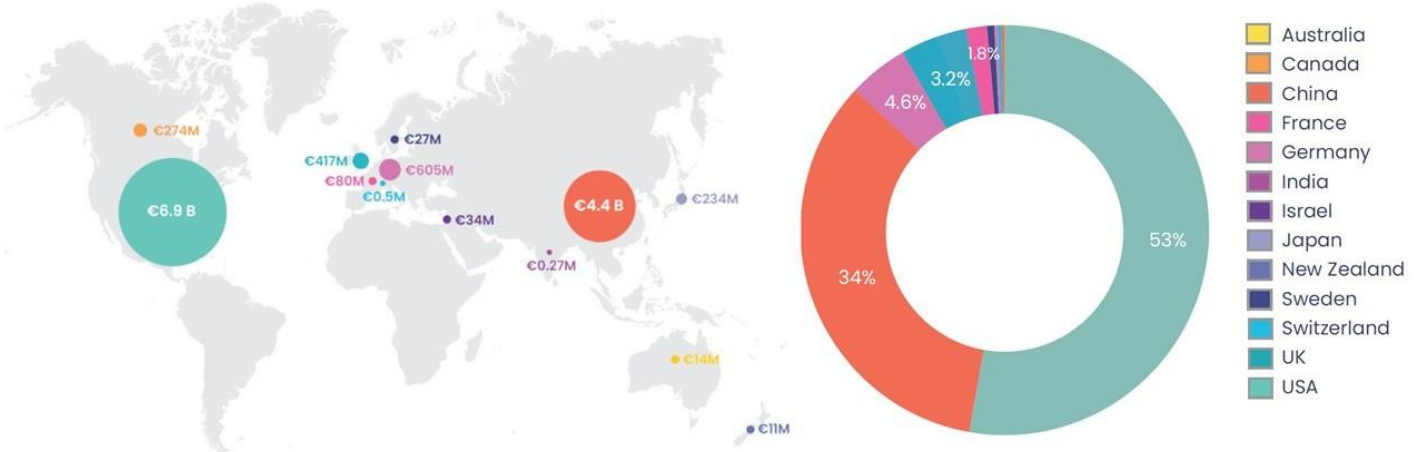


Left: Standard plate material
Right: Neutron irradiated structure with voids and blurred microstructure

Illustration with transparent metal layers for educational purpose by S. Wikman

Fusion Observatory Report
Second Release

- **Observatory now tracks 77 fusion companies & 400+ investors worldwide**
- **Global private fusion** up **30% since June 2025**, reaching **€13B**
- **US leads** with major deals — **CFS's €797M raise** and **$1B+ PPA with ENI**.
- **China steps up** with creation of **China Fusion Energy Co. (CFEC)**, with **€1.9B**.
- **EU gains momentum** — for example **Proxima Fusion raises €145M**, EU's largest-ever round.
- **Growth remains concentrated — US and China >85%** of total private funding.
- **EU share of private funding stable at 5% far behind US & China**



F4E FUSION OBSERVATORY