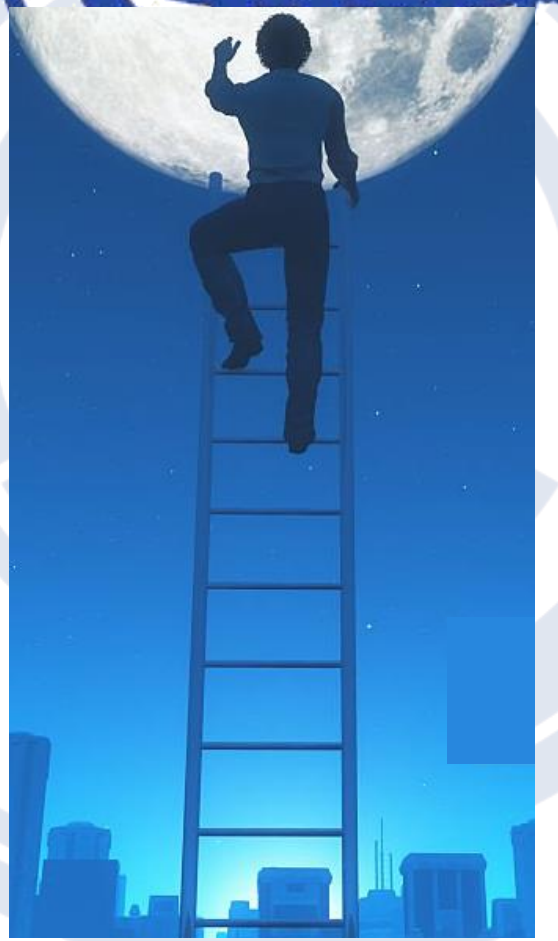
EUROfusion

SOFT34th
Aix-en-Provence (France)
22 September 2026

Towards a MCF enabling facility to address technology issues to deliver fusion



Gianfranco Federici
EUROfusion Programme Manager

Acknowledgments: DCT, WPDES and others

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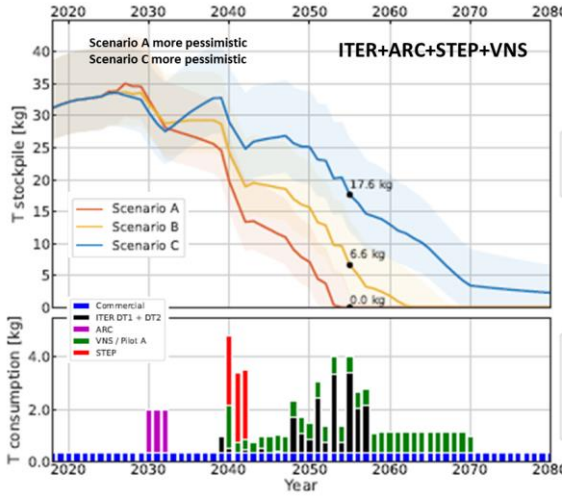
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Why? - A 14 MeV DT Pilot is needed to remove blanket showstoppers

Tritium Supply and Use

T is a very scarce resource – world availability for civil use is a few kg/year, with a cost of ~30 k€/g

T consumption in DT fusion is huge!



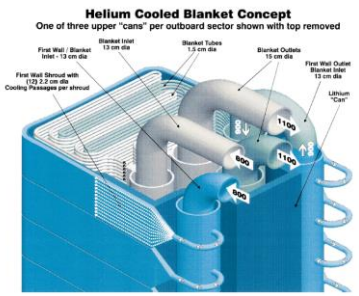
Source: M. Coleman (2026), UKAEA

- ✓ **DEMO ~185 kg T/GWe/fpy**
- ✓ **From CANDU: 0.21—0.26 kg T/GWe/fpy**

1) Need self-sufficient BB from day-1

Low TRL and large performance/reliability uncertainties of breeding blanket

- ✓ **After > 40 years of R&D, all blanket concepts suffer from issues**
- ✓ Attaining fuel self-sufficiency restricts design space and concepts



- ✓ **Testing in machines as complex as DEMO is unfeasible and extremely expensive** as for physics reasons, they have large power and sizes

2) Accelerate design & qualification of reliable T-breeding blankets

System reliability & plant availability

Need high power density
- High performance plasmas
- High performance plasma technology

Need low failure rates

$$COE = \frac{C_{\$}\,i + \text{replacement cost} + O\&M}{P_{fusion} \cdot \text{Availability} \cdot M \cdot \eta_{th}}$$

Energy multiplication

Need low failure rate
- Reliable power extraction technology

Need short maintenance time
- Simple configuration architecture
- Good access
- Easy to maintain in-vessel technologies

Need high temperature power extraction

$$A = \frac{MTBF}{MTBF + MTRR}$$

- ✓ **MTBF too short and MTRR too long**
- ✓ **Mostly unknown failure & modes rates**
- ✓ **Must establish a failure rate database to satisfy nuclear industry qualification & regulatory demands**

3) Address RAMI with rigor equal to that given to the plasma physics

Since 2023, EUROfusion is exploring a smaller-scale fusion devices (Pilot) serving as 14 MeV plasma-based VNS to enable testing at relevant n-flux and fluence levels, etc.

What? Objectives and design principles

High Level Objectives

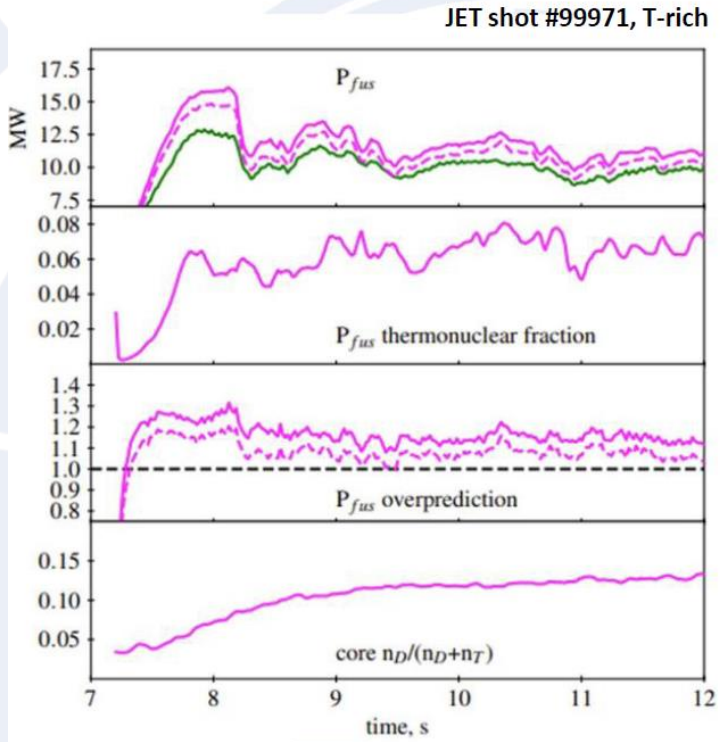
1. Built in parallel to ITER
2. Nuclear technology mission (DT plasma)
3. Breeding blanket & IVCs: concept validation, testing, qualification
4. **Not relying on T self-sufficiency**
5. Remote maintenance demonstration, build a fusion reliability database

Requirements/Design Principles

- **(from 1)** it must rely on a demonstrated physics – **beam/target (Q ≤ 1)** (e.g. JET T rich plasmas, see figure)
- **(from 2, 3)** Sufficient high level of n-flux → **must achieve a relevant NWL ≥ 0.4-0.5 MW/m²**
- **(from 2, 3) Must achieve relatively high fluence levels ≥10-20 dpa). Very long pulses are mandatory**
- **(from 4)** Operate with tritium from external supplies (non self sufficient) → **must minimize P_{fus} <50 MW**

Additional potential applications: production of radioisotopes, electricity demonstration (non-NET electricity), tritium production, amongst others.

Demonstrated on JET in DTE2 *[Maslov NF2023]* and DTE3 *[Maslov EPS2025]*



[Figure: M. Maslov et al., Nucl. Fusion 2023]

Main differences from ITER:

size, power, achievable neutron fluence

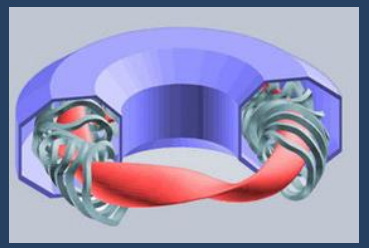
Main difference from DONES: irradiation volume (0.3 lt HFTM 1-300 lt MFTM in DONES vs 30 m^3) size of test articles

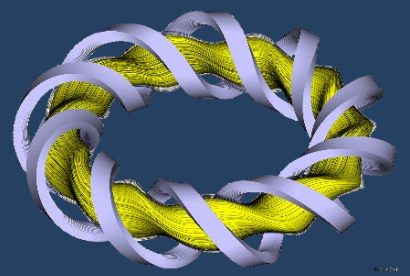
Beam-target fusion Pilot – feasible design options?

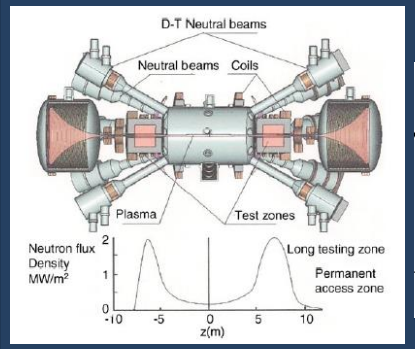


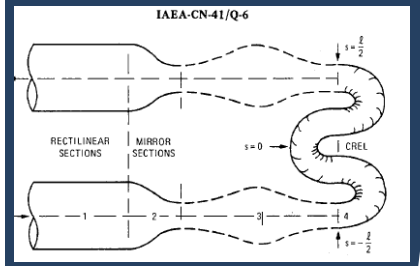
- FINESSE (1983-86)
- TASKA-M UW-KFK (1983-85)
- GDTs (Russian Federation 1990-today)
- IEA HVPNS Study (1995-96) and
- UCLA/GA/ORNL/Columbia Univ. joint study on FNSF (2009-2013)

- **This works builds on previous relevant studies (US, RF)**
- **Set high level requirements and design principles**
- **Identify main technical features and design/physics issues**
- **Screen and identify promising candidate concepts**



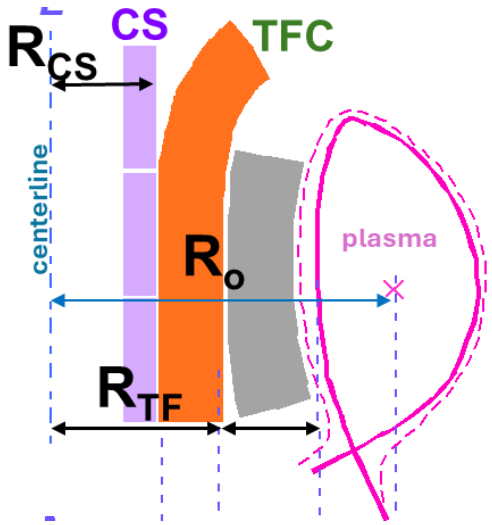


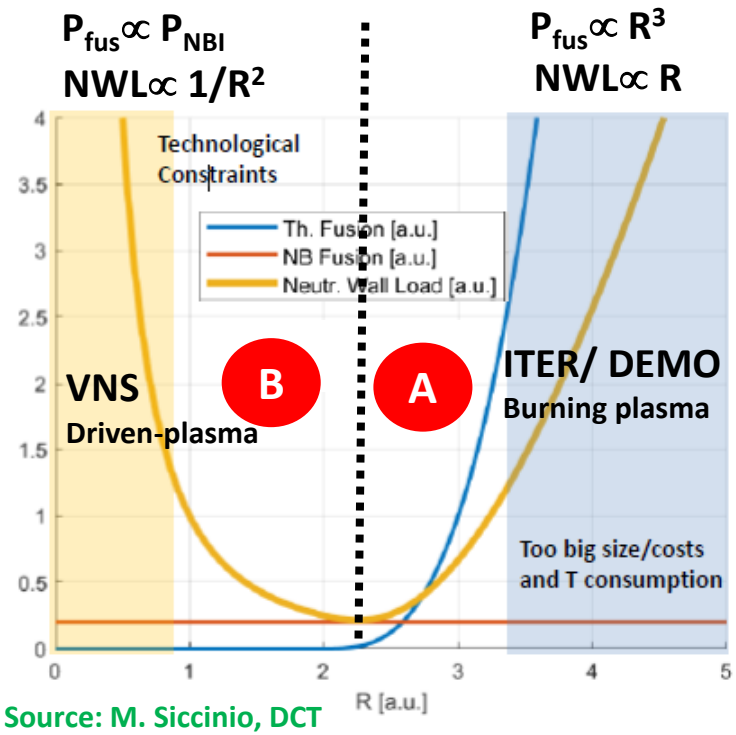




Stellarators	**Helias**	Mature performance/Steady-state operation Unfeasible because in a small device adjacent coils intersect
	Alternative: /Heliotron	Performance uncertain/ Lack of experimental validation
Linear devices, Mirrors	**GDT**	Still large physics uncertainties: confinement, Te, PWIs, PEX Design simplicity but problematic coils shielding Irradiation testing limitations: S_{VNS}/S_{GDT}=10 - V_{VNS}/V_{GDT}>100
	Alternative e.g., Dracon	Lack of experimental validation/Combines several configurations/Inherit the intrinsic drawbacks

Beam-target fusion Pilot – A possible shortcut





Source: M. Siccinio, DCT

A By "thermal", bulk plasma fusion one would need a large fusion power to get a sufficient NWL, i.e., a large size

B It relies on **beam-target fusion reactions**, using D beams on a T-rich plasma. P_{fus} depends only on beam power – no volume dependence $R_{fast\text{-}D\text{-}T} \sim \Gamma_{NBI\text{-}D} \times v_{D\text{-}fast} \times \sigma_{DT} \times T_e^{3/2}$

Optimal beam energy: 120-150 keV (compromise good penetration and high neutralisation efficiency)

Fusion power generation efficiency in such a plasma relies on:

- **Beam penetration**
- **Beam slowing down time** – *high T_e needed*

Background **plasma profiles have a strong impact** in determining the volume in which the beam-target reactions take place, i.e. on the fusion power

Design points were identified, small device size at high A are favoured for high NWLs

- Simplified models used to reach a preliminary definition of machine size and plasma scenario
- **Higher fidelity and integrated modelling tools** now used to confirm the device performance and consolidate the design point

Gaps and advantages

Physics issues:

- NBI torque comes with NBI CD
- NBI penetration vs loss of CD efficiency
- NBI penetration vs CD drive for Energetic Particle modes
- Power exhaust requirement

(being addressed by the physics community)

Engineering advantages and technical gaps:

- Machine and plant systems are mostly ITER technology
- Low manufacturability risks/established EU supply chain
- Assembly remain challenging
- Neutral beams: Reliability, pumping/regeneration/ RAMI
- Magnetic control: intra-vessel coils/inverted cage – placing PF inside the TF enclosure

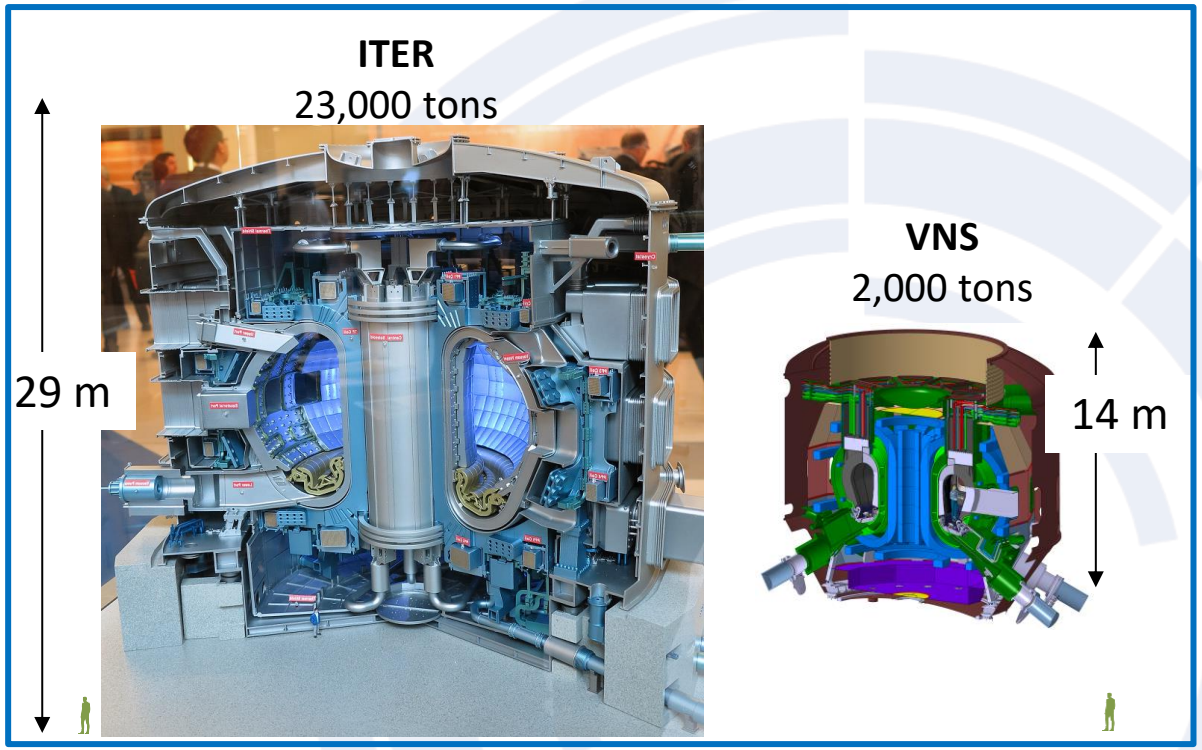
Operational advantages:

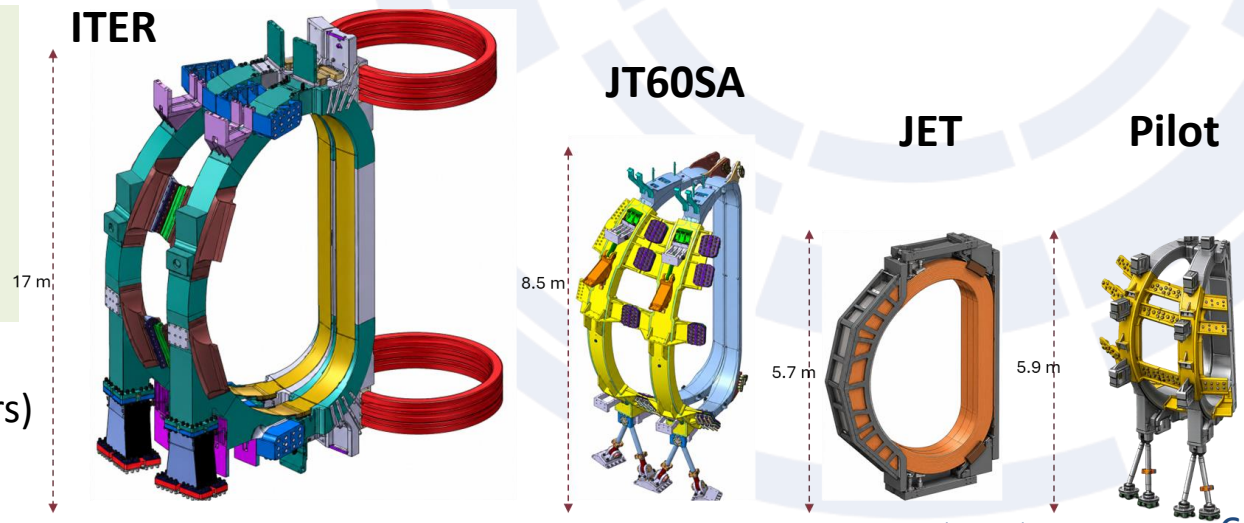
- Disruptions: a non-issue because of the modest plasma current
- Large testing areas and volumes
- Enable simultaneous testing of different concepts and coolants
- Enable n-testing test coupons, port TBM, outboard segments
- Enable establishing fully reactor-relevant RAMI database

Further potential:

- Blanket test platform for anybody (including start-ups/ intl partners)
- demonstrate (non-NET) electricity production and
- produce medical radioisotope as byproducts

Examples of design footprints





Key takeaways

- Fusion commercialisation is **not around the corner**, as many claim
- **ITER's & DT devices in construction have fundamental scientific confirmation & development missions**
- Investments and infrastructures are needed to solve **remaining technical gaps**
- **An enabling MCF facility offers a credible strategy to tackle remaining technology gaps not addressed by ITER**

Europe needs urgently a new fusion project complementary to ITER as a catalyst

1. **To fill outstanding fusion nuclear technical gaps** - *If we fail to develop and qualify robust solutions for the core fusion components, especially the breeding blanket fusion cannot move forward.* ***This will not be done by ITER***
2. **To elicit industry and supply chain interest and competences -** *Attractive opportunity for industry involvement in the near term.* ***Use the experience and tools of F4E and the PPP***
3. **To leverage important project forcing elements** - *engineering developments in key areas (nuclear performance, reliability, RH, safety).* ***Benefit from lessons learned from ITER design and construction***
4. **To draw political support and public/private funding** - *Motivate investors and governmental interest in the near term.* ***Realign Private and Public efforts towards common priorities. A testing platform used by everyone***
5. **To stimulates workforce development and to reestablish the leadership of Europe in fusion** - *Opportunity for training a new generation of scientists & engineers*

Related contributions @this conference

- **Physics**:
  - Clarisse Bourdelle: Plasma system in fusion plant design: challenges, uncertainties and perspectives, **Tuesday 4pm - Talk**
  - Andrea Quartararo: VNS design point optimization, **Monday S2-019**
  - Pasquale: Plasma vertical stability considering 3D structures of VNS, **Monday S1-048**
- **Magnets:**
  - Lorenzo Giannini: Magnet system of VNS, **Monday S2-018**
  - Aldo Di Zenobio: VNS TF coil conductor, **Wednesday BO-090**
- **VV + in-vessel components**
  - Bachmann: Engineering design of VNS, **Tuesday BO-108**
  - Aljaz Cufar: Neutronics - lower port of VNS, **Monday S2-17**
  - Domenico Marzullo: Divertor design, Thursday 3pm - **Talk**
- **Tritium, fuelling, vacuum:**
  - Haertl: Torus vacuum pumping of VNS, **Monday B0-089**
  - C. Hopf: Tritium inventory estimate of NBI in VNS, **Monday B0-090**
- **RH:**
  - Rocco Mozzillo: RH of VNS divertor, **Wednesday BO-069**
  - Donato Sorgente: RH of pipes - in-bore pipe cutting, **Wednesday BO-055**
  - A. Di Giacomo: RH of pipes - in-bore pipe cutting, **Wednesday BO-053**
  - Vincenzo Claps: RH of pipes - in-bore welding, **Wednesday BO-014**
  - Andrea Clagnan: VNS divertor fixation system, **Wednesday BO-015**
- **Safety**
  - Martina: Safety of VNS, **Thursday S2-001**

EUROfusion Values

FAIRNESS



Transparency
Collaboration
Loyalty

OPENNESS



Open doors
Open hearts
Open minds
Open ears

COMMITMENT



Ownership
Critical thinking
Determination
Respect

DIVERSITY



Cooperation
Equal opportunities
Inclusion

Thank you