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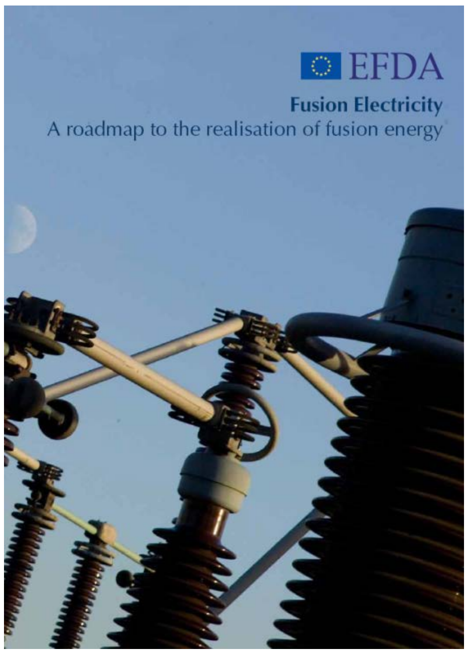
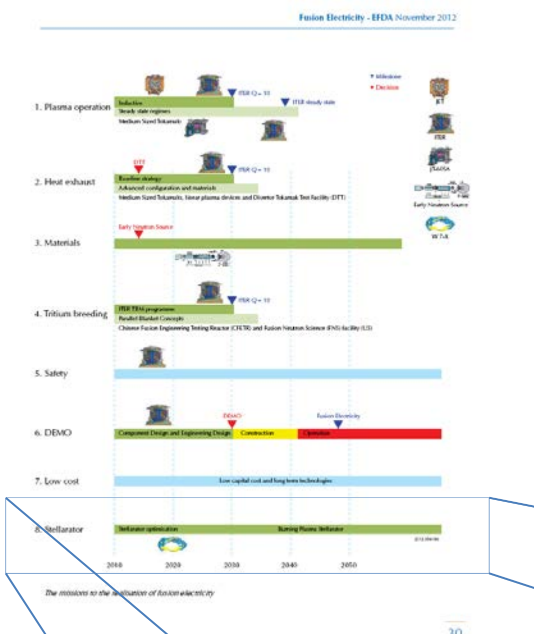
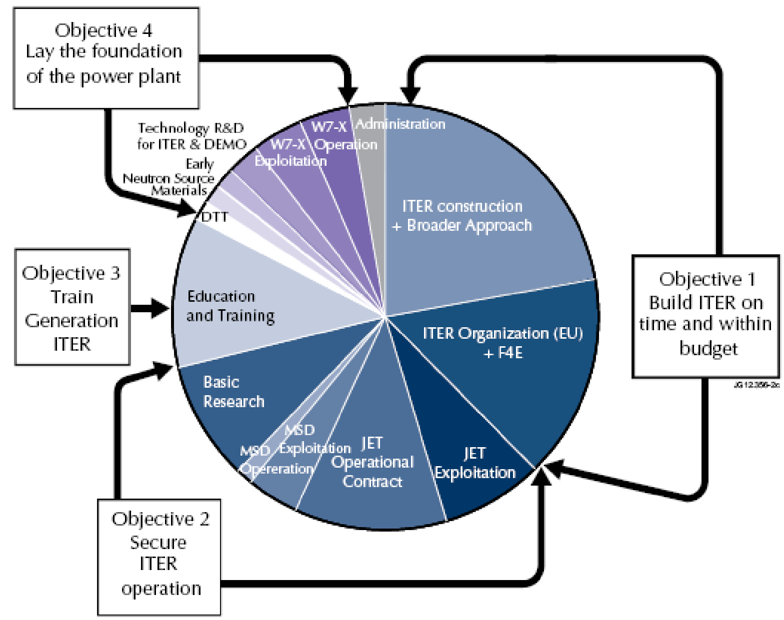
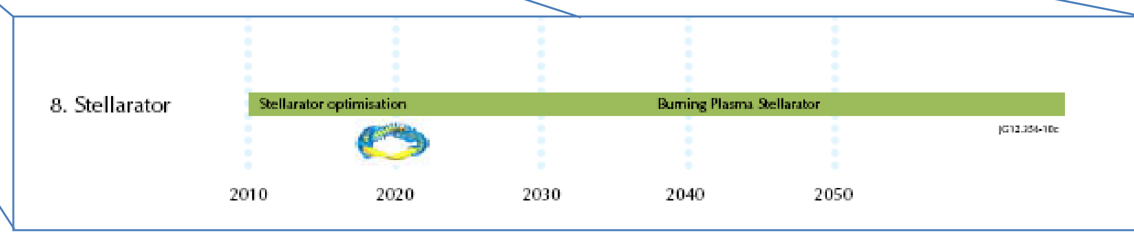
Stellarator Research within EUROfusion

The Roadmap to the realisation of fusion energy



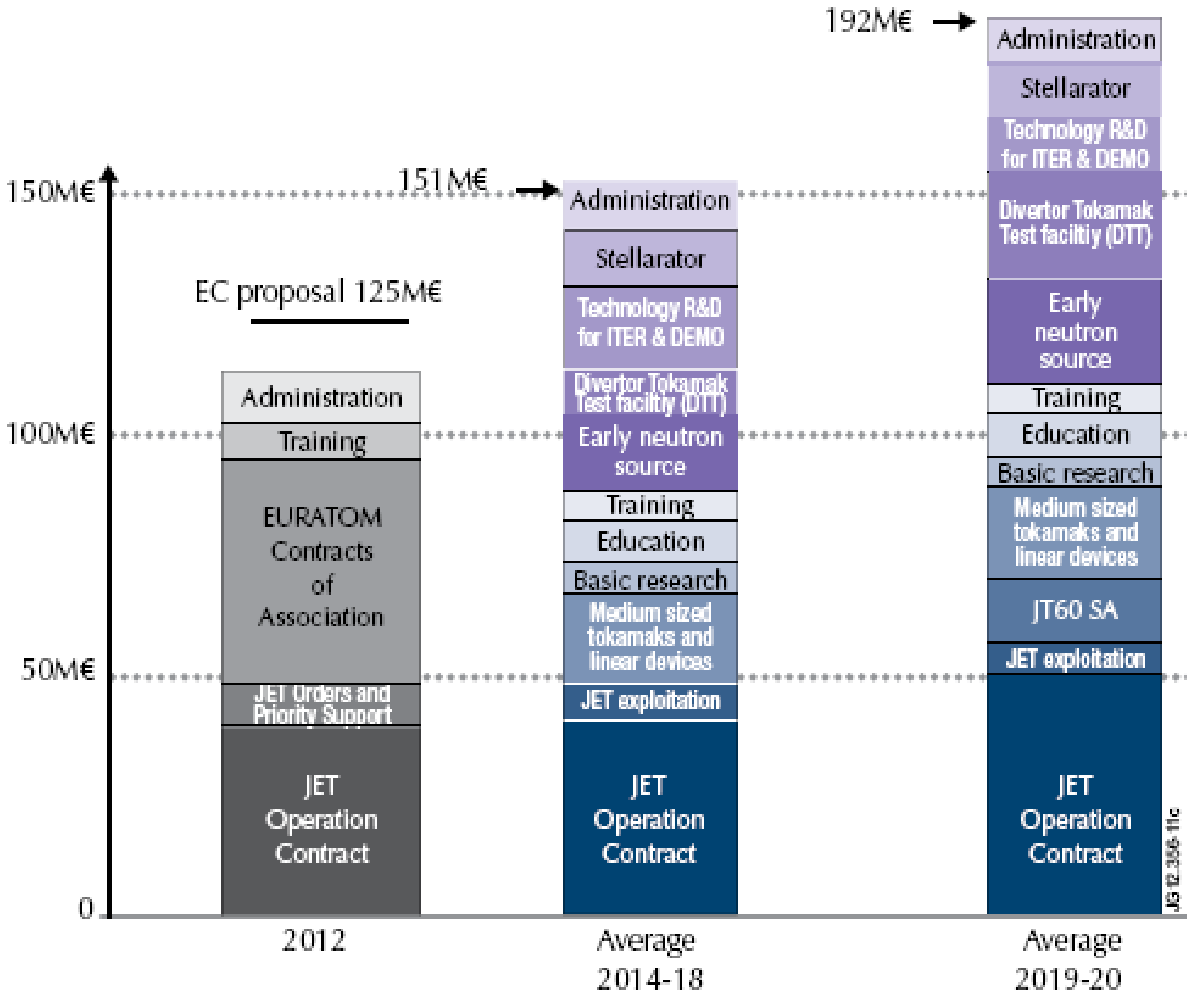






http://www.efda.org/wpcms/wp-content/uploads/2013/01/JG12.356-web.pdf

Funding & Resources



Average distribution of European Commission resources among the various roadmap activities (outside the ITER construction) together with the figure of 125M in the European Commission proposal for Horizon 2020[31].

The Stellarator Mission

Mission 8. Stellarator

In order to bring the stellarator configuration to maturity as a possible long-term alternative to tokamaks, the EU programme should focus on the optimised stellarator HELIAS line. Work on other stellarator lines (Heliotron, Compact stellarators) will continue as part of international collaborations. For the period 2014-2020, the main priority should be the completion and start of scientific exploitation of the W7-X experiment in validating the energy and particle confinement of optimised stellarators and qualifying the island divertor. Full qualification of solutions under steady-state conditions will be achieved beyond 2020. These activities will have also an impact on the progress of the basic understanding of plasma physics in support of Mission 1 and 2 and specifically in support of the ITER preparation. If W7-X confirms the good properties of optimised stellarators, a next step HELIAS burning plasma experimental device will be required to address the specific dynamics of a stellarator burning plasma. The exact goal of such a device can be decided only after a proper assessment of the W7-X results. In the long run, it is expected that this strategy could allow, together with the technology results from a tokamak DEMO, to build a stellarator FPP.

Research Strategy

Mission 8

Will be pursued through the exploitation of W7-X and targeted design studies for a stellarator reactor. First plasma on W7-X in 2015 and fully actively cooled components in 2019 are the main milestones for Horizon 2020.

Finally, following the results of W7-X a decision on how to progress with a next step stellarator device (**Mission 8**) will have to be taken in the second half of this decade.

The EU Stellarator programme should focus on the optimised HELIAS line.

The stellarator is a possible long-term alternative to a tokamak Fusion Power Plant. In addition, it provides a support to the ITER physics programme. For Horizon 2020, the main priority should be the completion and start of scientific exploitation of W7-X with full exploitation under steady-state conditions achieved beyond 2020. If W7-X confirms the good properties of optimised stellarators, a next step HELIAS burning plasma experimental device will be required to address the specific dynamics of a stellarator burning plasma. The exact goal of such a device can be decided only after a proper assessment of the W7-X results.

Implementation

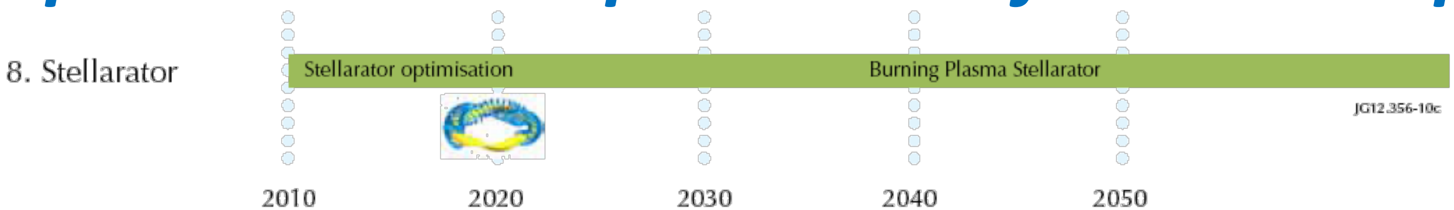
WPS1: Preparation and Exploitation of W-7X Campaigns

- Scenario development
  - Pulsed operation: 8 MW / 10 s to 1 MW / 1 minute (2016)
  - Limited D-operation (2017)
  - Development of credible scenarios for steady state operation (2017)
  - Qualification of heating schemes up to very high densities (2017)
  - Edge-iota control including ECCD (2018)
- Confinement studies
  - Verification of neoclassical confinement optimization (2016)
  - Study of impact of neoclassical optimization on turbulent transport (2017)
- Power and particle exhaust
  - Tailoring of island configuration (2017)
  - Qualification of safe divertor operation (2017)

WPS2: Stellarator optimisation: Theory Development, Modelling and Engineering

- Include engineering constraints in the stellarator optimization together with advances in physics understanding and computational capabilities
- Improve tools for predictive edge modelling for 3D geometries of stellarators
- Include turbulent transport models in the stellarator optimization, in addition to the neo-classic optimisation
- Develop new stellarator configurations, giving higher priority to fast ion confinement and less weight to aspects now deemed less crucial such as MHD stability.
- Stellarator reactor engineering and technology studies, including systems code design optimisation and costing studies, requirements analyses for blanket / shield, coil spacing, bend radius, superconductor type and properties; space requirements etc., diagnostic and heating system port and space requirements, RH requirements, remote handling space needs, etc.

S1: Preparation and Exploitation of W7-X Campaigns



WP-S1 implements with WP-S2 the *EUROfusion* contributions of Mission 8 of the Roadmap

Bring HELIAS to maturity as an alternative reactor concept

- priority in H2020: start scientific exploitation of W7-X
  – validate optimization concept
  – qualify island divertor
  – prepare steady-state operation
- cooperate with other lines (heliotron, compact stellarators)

WP-S1 – 2014

Actions 2014

- **0** seminars, mini-workshops, participation in program meetings etc. (w/ S2):
  - discuss and include ideas from the former Associations
- **A** preparation of operation and qualification of experiments (w/ S2):
  - prepare for a goal-oriented participation in and
  - operation of the physics program of W7-X (more specific for OP1.1, strategy for OP1.2)
  - identify W7-X relevant proposals
- *specifically: qualification at TJ-II (impurity transport, turbulent transport), cooperation w/ diagnostics actions, model validation (cooperation within SH-IA (IEA): JA, US, AUS, … and SSOCG (*
- **B** diagnostics/components and design activities:
  - continue work on known key diagnostics and components
  - W7-X relevant developments
  - identify W7-X relevant proposals
- *specifically: video, imaging software, reflectometry, soft-X, Langmuir probes, FPGA, ICRH*
- **C** modeling and preparation of experiments:
  - develop proposals for OP1.1 and refine strategy for OP1.2 (w/ S2)
  - identify W7-X relevant proposals
- *specifically: scenario development, predictive modeling (core&edge), advanced ECRH*

Headline 8.1: Qualification of Helias optimised stellarator operation **WP 14-18**

Roadmap PWPs: 8.1, 8.2, 8.3

With regard to the reactor physics basis, the validation of the energy and particle confinement of optimised stellarators is one of the main objectives of the W7-X experiment. The neoclassic part of the physics underlying these optimisation goals is considered to be well understood and it is quite likely that the achievement of several of these goals concerning neoclassical behaviour can already be verified during the Horizon 2020. However, due to the power limitation in the early phase W7-X of operation, it is uncertain whether sufficiently high beta values will be reached in this phase of operation and whether the role of turbulent transport can be fully assessed. Even after all optimisation goals of the W7-X experiment will have been demonstrated, advanced stellarators will only become attractive reactor candidates if they can maintain high-performance (high-β, low-ν^*, low-ρ^*) steady-state plasmas (discharges of several minutes. This is required to surpass all physical and technical time constants of relevance) with viable Divertor performance (high radiated-power fraction with at least partial detachment) without loss of density control and without impurity accumulation. As a superconducting device with 10 MW continuous (over 30 minutes) of ECRH and a high-heat-flux divertor capable of handling power loads of 10 MW/m2 (following initial operation with an inertially cooled divertor), the W7-X experiment will possess the technical capabilities necessary to achieve such integrated reactor-relevant scenarios. The investigation of steady-state plasmas will be the main objective of the second phase of the W7-X experimental programme, probably starting only at the end or after Horizon 2020.