Implementing Agreement for Co-operation in Development of the Stellarator-Heliotron Concept

(SH-IA)

Strategic Plan

2016 - 2021

November 2015

Energy Technology Network

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1. **Introduction**

In October 2015, the annual meeting of the Stellarator-Heliotron IA ExCo was held in Greifswald, Germany, on the occasion of the 20th International Stellarator-Heliotron Workshop. Following a discussion about the achievements in the past term (2010-2015) and also about the prospects for the future, the ExCo concluded with a unanimous agreement to seek a 5-year (2016-2021) extension of the Stellarator-Heliotron IA.

An international workshop on the Strategy of Stellarator-Heliotron Research was held on March 4-6, 2015 in Nagoya, Japan. The workshop was initiated by the Research Enhancement Strategy Office of the National Institute for Fusion Science (NIFS), Japan. Representatives of all the Stellarator-Heliotron IA contracting parties participated sharing their views on the international collaboration perspectives to strengthen the Stellarator-Heliotron research. The details of this workshop were reported in the Stellarator News [Issue 147, Apr. 2015, http://web.ornl.gov/sci/fed/stelnews/].

Participants at the International Workshop on the Strategy of Stellarator-Heliotron Research, March 4-6, 2015, Nagoya, Japan.

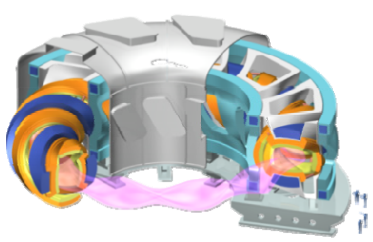
2. Strategic Direction and Scope

The aim of the research on magnetic confinement fusion is the realization of a new CO_2-free primary energy source with advantageous safety properties. To date this is the only conceivable new form of a primary energy source. The main development line in fusion research is the tokamak line. Stellarators and heliotrons constitute a promising alternative with advantageous properties, such as steady-state confinement with the prospect of developing a more economic power plant concept. All the collaborative activities of the worldwide stellarator and heliotron research are combined under the umbrella of the Stellarator-Heliotron Implementing Agreement.

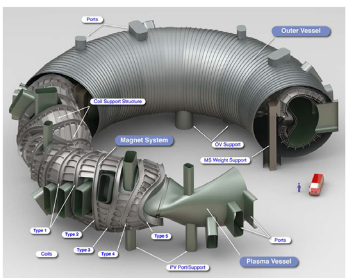
The main strategic direction of the IA will not change. The Stellarator-Heliotron IA will continue to promote the exchange of information among the partners, the assignment of specialists to facilities and research groups of the contracting parties, joint planning and coordination of experimental programmes in selected areas, joint experiments, workshops, seminars and symposia, joint theoretical and design and system studies, and the exchange of computer codes. A major new element will be the scientific exploitation of the superconducting optimized stellarator Wendelstein 7-X (W7-X, Greifswald, Germany), the construction of which has been completed in 2014 and which has been successfully commissioned up to magnetic fields of 2.5 T. First plasma operations are expected to start by the end of the year 2015.

Overall, the main focus of the IA will be the further promotion of the Stellarator-Heliotron concept. The focus of the worldwide tokamak development is ITER. The main objective of ITER is to demonstrate for the first time a burning fusion plasma with a positive power balance and significant self-heating of the plasma by the fusion reactions. In this context, it is increasingly being realized that stellarators and heliotrons may not only be a very promising alternative for a future fusion power plant, but also that the understanding of the more complex three-dimensional confinement properties of stellarators and heliotrons is indispensable for the further development of tokamaks. The promotion of the synergies between tokamaks and stellarators and heliotrons is therefore a central part of the strategic direction of the IA. An important mechanism to foster such synergies is the participation of a representative of the Stellarator-Heliotron IA in each topical group of the International Tokamak Physics Activity (ITPA). Within the IA, the Coordinated Working Group Meeting (CWGM) is organizing the research activities.

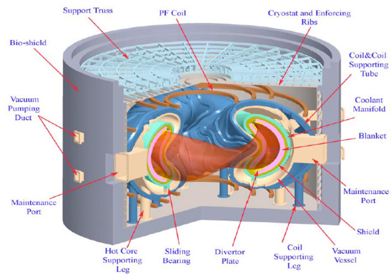
As outlined in the Fusion Power Co-ordinating Committee (FPCC) strategic plan 2015-2017, a major strategic objective is the development of the physics and technology basis for a fusion demonstration power plant. Based on the enhancement of physics understandings and accumulated experimental database, conceptual reactor designs have progressed based on Stellarator-Heliotron concepts. The representative three designs as shown below are the FFHR (LHD-type, Japan), HELIAS (Wendelstein line, EU) and ARIES-CS (compact stellarator concept, US). Systems code such as HELIOSCOPE [e.g. T. Goto et al., Nuclear Fusion 51 (2011) 083045] and PROCESS [e. g., F. Warmer et al., to appear in Fusion Science and Technology (2015)] have been developed and applied to advance the designs. More importantly, these reactor design and systems code activities have been closely involved in the CWGM activities since 2010. The highlights of these systems studies have been presented at conferences and workshops such as the IAEA DEMO workshop series.



FFHR



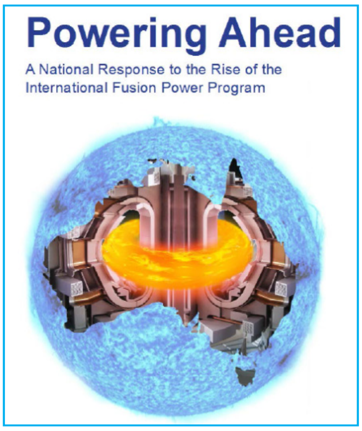
HELIAS



ARIES-CS

The directions of this strategy are also reflected in the strategies of the contracting parties of the IA:

- Australia

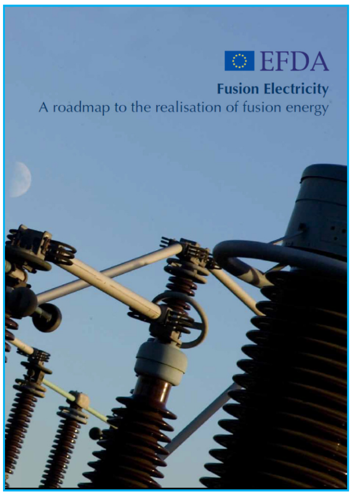


The Australian Fusion Science Strategic Plan "Powering Ahead" was launched in July 2014. It includes the upgrades to H-1NF stellarator, the MAGPIE materials interaction facility and requests funding to participate in ITPA and CWGM activities.

H-1NF has the design flexibility to explore many different non-axisymmetric 3D confinement configurations. Its unique construction also provides unparalleled observational access to the plasma. As a university-scale device, it also has the operational flexibility to adapt quickly to new challenges and changing priorities. Given the resurgence of interest in the physics of non-axisymmetric confinement systems, the recently upgraded H-1NF is well poised to make contributions to the international fusion program. Its inherent non-axisymmetry and diagnostic access also makes it an ideal test bed for developing 3D imaging systems of the kind proposed for the divertor region of ITER.

An outward looking Australian fusion program will provide support for program-focused fellowships, international exchange of scientists and research students, and travel associated with membership of international fusion-related committees. The main collaborations under the IA are currently with Japan, Germany, USA and Ukraine.

- European Union (Spain and Germany)



Within the EU, the fusion programme was reorganized completely. Together with the establishing the EUROfusion consortium which receives funding from European Commission, the work is now organized in projects which are aligned with the European Fusion Roadmap (www.euro-fusion.org/wpcms/wp-content/uploads/2013/01/JG12.356 - web.pdf) which forms the programmatic basis of the work of the EUROfusion consortium.

As part of the roadmap, stellarator research is recognized as one of seven high-priority missions. In order to bring the stellarator configuration to maturity as a possible long-term alternative to tokamaks, the EU programme focuses on the optimized stellarator (helical advanced stellarator of the HELIAS line). Research on other stellarator lines (heliotrons, compact stellarators) will continue as part of international collaborations. Here, the Stellarator-Heliotron IA will be essential. For the period 2015-2020, the main priority will be the start of the scientific exploitation of the W7-X experiment and the completion of the device to achieve the full steady-state capability.

The TJ-II experiment at CIEMAT will play important roles to support the W7-X program in the framework of EUROfusion. Thus, the TJ-II research programme will be more mission-oriented to support W7-X and international Stellarator-Heliotron research.

- Japan

In Japan, two heliotrons are part of the IA. The Large Helical Device (LHD) at the Institute of Fusion Science (NIFS) will gain a very important new element for its research capability. Creating high temperature plasmas with deuterium will make it possible to study the influence of the hydrogen isotope on plasma confinement, which in tokamaks is a very robust effect. LHD also assumes a distinguished position in the "Report by the Joint-Core Team for the Establishment of Technology Bases Required for the Development of a Fusion DEMO Reactor – Chart of Establishment of Technology Bases for DEMO", released by the (domestic) Joint-Core Team in early 2015 [http://www.naka.jaea.go.jp/english/index.html], for divertor research in the steady-state environment with upgraded heating power.

The main objective of Heliotron-J at the University of Kyoto is the experimental optimization of the helical-axis Heliotron configuration. The research topics will be investigated also by promoting international collaborations.

- Russia

The Kurchatov institute fosters collaborations beyond ITER, including research in radio-frequency heating and long term collaborations with the Stellarator-Heliotron community. It strongly supports the further development of such collaborative efforts focusing on steady-state operation and the design and construction of DT-fusion devices. The current experiments on electron-cyclotron-resonance heated plasmas in the stellarator L-2M (General Physics Institute) are capable to produce high power density and keV electron temperature. Theory activities related to stellarators and heliotrons cover a wide range of topics.

- Ukraine

The mid-term plans comprise developments of a fusion-fission hybrid (theory and experiment). Studies on Uragan stellarators support the international stellarator and heliotron research and also include a concept of a fusion-fission hybrid.

- United States

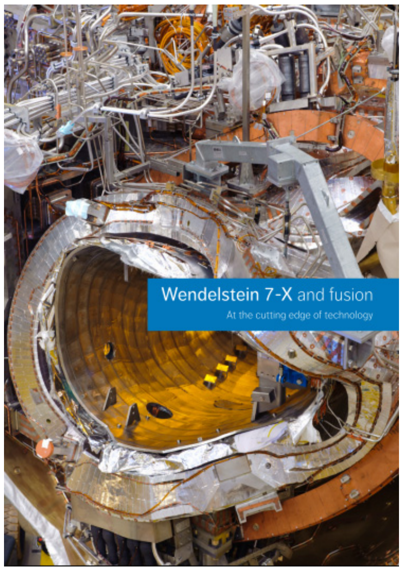
Burning plasma science (DoE, Office of Science) has focused on long-pulse tokamaks and Stellarator-Heliotrons, by using partnerships on international facilities where US expertise is valuable and desired, thereby generating access for US scientists and students to what are becoming leading research endeavours around the globe.

A consistent and coherent advocacy for Stellarator-Heliotron research has been maintained via a self-organized "National Stellarator Steering Committee".

A US team is strongly collaborating on the Wendelstein 7-X. The US domestic efforts focus on optimizing the stellarator concept through compact quasi-symmetric magnetic field shaping (HSX), and on providing data relevant to mainline Stellarator-Heliotron efforts, validating models and codes (such as equilibrium reconstruction, CTH).

3. IA Performance

Contribution to technology evolution / progress



The contributions of IA activities to technology evolution have been strong and will continue to do so. The technology developments associated with the leading experimental devices, such as LHD and W7-X have an impact beyond the Stellarator-Heliotron community and also beyond fusion research. Examples are superconductor technology, high heat flux steady-state components or high-power microwave tubes (gyrotrons). The fusion technology award of the Institute of Electrical and Electronics Engineers (IEEE), awarded to Dr. F. Schauer in 2014 for his contributions to the development of superconducting magnets and stellarator power plant studies, shows the far reaching recognition of the field.

Contribution to environmental protection, technology deployment and market facilitation

Obviously, a long term R&D program such as fusion research can hardly make immediate contributions to environmental protection and market facilitation. Nevertheless, technology deployment and facilitating the competitiveness of companies and industries takes place through placing contracts for high-tech components or engaging in joint technology developments with industry. For the construction of Wendelstein 7-X prominent examples have been collected in a special brochure explaining the views of the companies involved [www.ipp.mpg.de/987655/w7x_and_industry_en.pdf].

Contractual and Management Requirements

As the main strategic objectives of the IA remain unchanged and the organizational structure as well as the legal framework have proven effective in reducing the transactional cost of collaborations, there are no plans to change the management structure as well as the legal text of the IA.

Contribution to information dissemination

The annual report and the IA website will continue to be the central channels of outside communication of the IA, as especially the annual report has proven to be an important tool for delegates to inform their governments on the activities and the achievements of the IA, and the cost effectiveness of their participation. It is intended to further develop these channels by improving and streamlining both presentation and content. In addition, the ExCo aims to more effectively promote the IA as a part of the Energy Technology Network, e.g. by supplying the IEA secretariat with regular and focused updates on research highlights and by the more prominent use of the Energy Technology Network Logo for IA events.

Policy relevance

The ExCo delegates will continue to provide decision makers with updates on the development and the achievements of the Stellarator-Heliotron research program. Moreover, as the upcoming start of Wendelstein 7-X has significantly raised the awareness for stellarator research; the IA will build upon this gained recognition to promote fusion research and the stellarator-heliotron line in particular by informing policy makers and by helping to shape research policy through their participation in national and international decision-making bodies.

Outreach to IEA non-Member Countries

Both the Russian Federation and Ukraine have been long-standing participants of the IA and will continue to do so. Also, with the increasing recognition of stellarator-heliotron research, the interest of non-member countries in the research field of the IA is growing as well. 217 participants from 18 countries, among them four non-member countries at the 20th International Stellarator-Heliotron Workshop (ISHW) in Greifswald served as proof for the worldwide interest in the activities of the IA.

Participants of 20th ISHW (© IPP, M. Borchardt)

4. Summary

The Stellarator-Heliotron IA will continue to play a leading role to programmatically advance world-side stellarator-heliotron research, and to strategically strengthen the links with other concepts of fusion development. Two large superconducting devices, Wendelstein 7-X and LHD, will be flagships of stellarator-heliotron research in the coming period of the IA. The ExCo (one meeting per year), the CWGM (up to two meetings a year) and the International Stellarator-Heliotron Workshop, which takes place every two years, will act as joint forums to further extend our international partnerships.