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

(SH-IA)

End-of-Term Report

2010 - 2015

November 2015

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1 Executive Summary

The IEA Implementing Agreement for Co-operation in Development of the Stellarator-Heliotron Concept (SH-IA, the name Heliotron was added at the occasion of the last extension in 2010) has been operational since 1985 and, after the incorporation of Ukraine in 2002, it presently involves the participation of six parties, namely: Australia, the European Union, Japan, Russia, Ukraine, and the United States. The very successful and fruitful cooperation resulting in many important new scientific results during the period of 2010-2015 under the auspices of the SH-IA fully justify the extension of the Agreement.

Stellarator-Heliotron's potentially unique feature, inherent favorable characteristics for steady-state operation, makes this concept an invaluable alternative to tokamaks in the development of future fusion power plants. Contrary to tokamaks, Stellarator-Heliotrons can create the magnetic field without requiring a net toroidal plasma current, which makes auxiliary current drive unnecessary and brings remarkable advantages for the plasma stability, in particular the absence of plasma current disruptions, and a significant reduction of circulating power in a power plant. In this way, steady-state operation would be intrinsically and safely achieved in a Stellarator-Heliotron reactor. Also, the enhancement of the understanding of three-dimensional physics in Stellarators-Heliotrons has greatly contributed to the progress of physics in tokamaks.

The SH-IA has pursued the advancement and coordination of the promising Stellarator-Heliotron concept towards a fusion reactor, which will provide environmentally friendly, safe and abundant energy. The Stellarator-Heliotron concept has allowed for the exploration of a wide range of physics and technological issues in the variety of topological configurations available to the parties. The exchange of knowledge and views, including joint participation in experiments and compilation of databases, as well as a coordinated strategy definition and planning, have greatly strengthened the research on the Stellarator-Heliotron concept over the past five years.

The collaborations within the IEA framework were very active and successful for the period of 2010-2015, evidenced by the fruitful collaborations summarized in this document. All participating countries have greatly benefited from these collaborations. Exploiting a leading large-scale experiment as the Large Helical Device (Japan) and Wendelstein 7-X (Germany), other experiments constructs a broader and firmer basis for the development of a Stellarator-Heliotron concept than before. These results and promising prospects as well as the large number of scientific collaborations in the coming years make the extension of the agreement highly desirable.

2 Strategic Direction

The Stellarator-Heliotron concept has been an alternative confinement approach to the Tokamak concept for future fusion power plants. Significant progress of this concept has been made for the period of 2010-2015.

The SH-IA provides mechanisms to jointly investigate the properties of different Stellarator-Heliotron approaches and to compare them with the Tokamak concept. For example, a joint international Stellarator-Heliotron confinement (energy confinement time) and profile (measured profiles along with the corresponding three-dimensional equilibrium) database [ISH-C(P)DB] including experimental results from participating facilities is a representative activity under the SH-IA.

The Executive Committee (ExCo) has systematically guided co-ordinated activates such as the ISH-C(P)DB, the Coordinated Working Group Meeting (CWGM), and of course, the research community's regular workshop, the International Stellarator-Heliotron Workshop (ISHW, held every 2 years). In this way, the Executive Committee has compiled international joint programmes and strategic plans.

The collaboration programme includes jointly planned experiments for comparison purposes, mutual participation in experiments and theory/simulation activities, joint evaluation of results, and information sharing. Exploiting a larger number of devices provides a broader basis of experimental results, better progress on physics understandings and increases the reliability of the results from the various facilities, thus contributing to improve the design of next-step devices and the DEMO reactor towards realization of a fusion power plant.

Over the past five years, the flag-ship experiment has been the Large Helical Device (LHD) in Japan, which has significantly advanced the relevance of the Stellarator-Heliotron concept to a future fusion power plant in terms of steady-state (long-pulse) and high-performance (high-ion-temperature, high density) plasma confinement capability. Along with LHD's leading role in the Stellarator-Heliotron research, the SH-IA chair was served by Prof. Akio Komori (the Director-General of the National Institute for Fusion Science until March 2015).

Another large-scale experimental device – Wendelstein 7-X (W7-X) in Germany – has been successfully commissioned and will start with experiment operations before the end of the year 2015. The start of W7-X experiments certainly indicates a new era of Stellarator-Heliotron research; a vigorously competitive and comparative collaboration is envisaged. Anticipating the active role of W7-X to further facilitate the Stellarator-Heliotron research, the ExCo has elected Prof. Robert Wolf (director of the Stellarator Heating and Optimization Division, Max-Planck Institute for Plasma Physics, Greifswald) as chair during the ExCo meeting in October 2015.

3 Scope of Activities

The current strategic objectives of the SH-IA are (as formulated in the IA legal text):

- exchange of information;
- assignment of specialists to the facilities or research groups of the contracting parties;
- joint planning and co-ordination of experimental programs in selected areas;
- workshops, seminars and symposia;
- joint theoretical, design and system studies;
- exchanges of computer codes; and
- joint experiments.

These programmatic joint actions have facilitated the usage of experimental devices, numerical codes, obtained data etc. in participating institutions, and the systematization of academic outcomes.

To facilitate these activities in programmatic ways, the following actions have been taken in the past five years:

- International Stellarator-Heliotron Workshop (ISHW) See 3.1
- Coordinated Working Group Meeting (CWGM) See 3.2
- Executive Committee (ExCo) meetings See 3.3

3.1 International Stellarator-Heliotron Workshop (ISHW)

Over the past five years, three ISHW meetings were held as follows:

No.	Place	Date	Number of presentations	Remarks *Web-link, Local Organizing Committee (LOC) and Program Committee (PC) chairs, proceedings*
18	Canberra and Murramarang, Australia	Jan. 29 - Feb. 3, 2012	>120	http://plasma2012.org.au/ LOC chair: B. Blackwell (Australian National University) PC chair: M. Zarnstorff (Princeton Plasma Physics Laboratory) Plasma Physics and Controlled Fusion 55, Nr.1 (2013)
19	Padova, Italy	Sept. 16 - 20, 2013	168	http://www.igi.cnr.it/ish_rfp_ws2013/ LOC chair: D. Terranova (Consorzio RFX) PC chair: B. Blackwell and M. E. Puiatti (Australian National University and Consorzio RFX) Plasma Physics and Controlled Fusion 56, No. 9 (2014)
20	Greifswald, Germany	Oct. 5 - 9, 2015	162	http://www.ipp.mpg.de/3523924/ishw_2015 LOC chair: P. Helander (Max-Planck Institute for Plasma Physics) PC chair: K. Ida (National Institute for Fusion Science) t. b. p. in Plasma Physics and Controlled Fusion

3.2 Coordinated Working Group Meetings (CWGM)

Over the past five years, seven CWGM meetings were held:

No.	Place	Date	Number of presentations	Remarks *Topics discussed, significant outcomes etc.*
7	Max-Planck Institute for Plasma Physics Greifswald, Germany	Jun. 30 - Jul. 2, 2010	38	Edge turbulence database, magnetic topology, transport model validation, MHD and high beta, H mode, database issues, three-dimensional equilibrium, joint experiments Stellarator-Heliotron representatives were dispatched to the "Three-dimension physics" session of the ITPA (International Tokamak Physics Activity)
8	National Institute for Fusion Science Toki, Japan	Mar. 16 - 17, 2011	19	Magnetic topology, H mode, database issues, energetic particles
9	Australian National University Canberra, Australia	Jan. 28, 2012	12	Energetic particles, equilibrium in experiment, transport analyses, plasma rotation, fueling, H1-NF contribution (data process updates)
10	Max-Planck Institute for Plasma Physics Greifswald, Germany	Jun. 6 - 8, 2012	34	10th Anniversary (Evolution of CWGM activity) Contribution to ITPA, resonant magnetic perturbation, wall conditioning, three-dimensional equilibrium, flows and viscosity, transport validation, particle transport, transport issues, Alfvén eigenmodes/energetic particles, database issues, reactor/system design Kick-off for establishing interlinks between physics systemization and reactor/system design in CWGM
11	CIEMAT Madrid, Spain	Mar. 11 - 13, 2013	33	Flows and viscosity, three-dimensional equilibrium, database issues, energetic particles, transport, island dynamics, link to ITPA Integrated Operation Scenario topical group, H mode, reactor/systems code, joint experiment
12	Padova, Italy	Sept. 20, 2013	4	Transport validation, flows and viscosity, Alfven eigenmodes/energetic particles, link to ITPA Discussion on the joint activities based on the presentations of 19th ISHW
13	Kyoto University Uji, Japan	Feb. 26 - 28, 2014	33	Highlights in experiment/Invitation to joint experiment, framework of collaborations, Stellarator-Heliotron database, 3D transport in divertors, impurity, reactor/systems code, flows and viscosity, turbulent transport, plasma startup, Alfven eigenmodes/energetic particles, three-dimensional equilibrium
14	Institute of Plasma Physics and Laser Microfusion Warsaw, Poland	Jun. 17 - 19, 2015	29	First CWGM in Poland (outreach in relation to EUROfusion Stellarator mission) Kick-off of impurity session as a standing session. Strategic collaboration, Alfven eigenmodes/ energetic particles, updates in several experiment

	devices, impurity transport, diagnostics, fuelling/particle transport

All information is available through http://ishcdb.nifs.ac.jp/.

3.3 Executive Committee (ExCo) meetings

Over the past five years, six ExCo meetings were held as follows:

No.	Place	Date	Number of participants (including observers)	Agenda to be specially remarked
39	Daejeon, Korea (on occasion of the 23rd IAEA Fusion Energy Conference)	Oct. 12, 2010	19 Chair: Prof. O. Motojima	Report of approved IA extension (valid until 30 June 2016, Stellarator-"Heliotron") Discussion how to organize 18th ISHW (Australia) Cooperation on steady state operations (towards initiation of the cooperation on Steady-state operation: now SSOCG: Steady-state Operations Co-ordination Group)
40	Canberra, Australia (on occasion of the 18th ISHW)	Jan. 30, 2012	11 Chair: H. Yamada, as substitute to Prof. O. Motojima	Chairmanship (reflecting Prof. O. Motojima's concurrent situation between SH-IA chair and the ITER Director-General) Discussion how to organize 19th ISHW: Contact to RFP colleagues for joint workshop based on increasing mutual interests on "three-dimensional" physics → realized
41	San Diego, USA (on occasion of the 24th IAEA Fusion Energy Conference)	Oct. 9, 2012	14 Chair: Prof. O. Motojima succeeded by Prof. A. Komori	Chairmanship was transferred from Prof. O. Motojima to Prof. A. Komori (based on discussions at and after the 40th ExCo) Preparation for 19th ISHW (joint session with RFP workshop)
42	Padova, Italy (on the occasion of 19th ISHW)	Sept. 17, 2013	12 Chair: H. Yamada, as substitute to Prof. A. Komori	Discussion how to organize 20th ISHW Discussion on SSOCG activity (report from Prof. T. Mutoh, who is the co-chair of SSOCG)
43	St. Petersburg, Russia (on occasion of the 25th IAEA Fusion Energy Conference)	Oct. 16, 2014	14 (incl. remote participants) Chair: Prof. A. Komori	Discussion on the chairmanship (agreed to transfer from Prof. A. Komori to someone from Max-Planck Institute for Plasma Physics, at the next ExCo, reflecting the anticipated start of the operation of the W7-X). Preparation for the IA extension (request for the extension for 5 years was unanimously agreed) (Raised by Ms. C. Pottinger, after the meeting) difficulties on steady communications with Russian representatives should be resolved → Two new Russian representatives were endorsed by ROSATOM, and now steady communications haven been maintained.

44	Greifswald, Germany (on occasion of the 20th ISHW)	Oct. 6, 2015	14 Chair: Prof. A. Komori succeeded by Prof. R. Wolf	Election of chairman and vice chairmen Discussion on draft documents for IA extension (to be submitted soon after this ExCo) Discussion on the host of the 21st ISHW Russian representative (substitute) participated on site. Lars-Goran Eriksson was appointed as an observer for the European Commission

4 Contractual and Management Requirements

4.1 Executive Committee Membership

Members of the Executive Committee per the 44th ExCo meeting are:

Contracting party	Country	Name	Affiliation
ANU	Australia	B. Blackwell	The Australian National University
		J.H. Harris	The Australian National University
EURATOM	Germany	R. Wolf (Chair) T. Klinger (alternate)	Max-Planck-Institute for Plasma Physics
	Spain	J. Sanchez C. Hidalgo (alternate)	CIEMAT
NIFS	Japan	Y. Takeiri (Vice Chair)	National Institute for Fusion Science
		T. Morisaki	National Institute for Fusion Science
ROSATOM	Russia	B. Kuteev	National Research Center, Kurchatov Institute
		V. Ivanov	Prokhorov General Physics Institute of Russian Academy of Sciences
NSC	Ukraine	I.E. Garkusha	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
		V.S. Voitsenya	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
US DOE	USA	D.T. Anderson	Wisconsin University
		M.C. Zarnstorff (Vice Chair)	Princeton Plasma Physics Laboratory
Observers		C. Pottinger	IEA
		L.G. Eriksson	European Commission
		T. Mutoh (SSOCG Co-Chair)	National Institute for Fusion Science
		M. Yokoyama	National Institute for Fusion Science
		P.Kurz (Secretary)	Max-Planck-Institute for Plasma Physics

4.2 Executive Committee Meeting

ExCo-meetings have been held once a year and played a supervisory role for facilitating the programmatic joint actions for Stellarator-Heliotron concept development as documented in the IA legal text. One exception is 2011 due to the fact that the ISHW (the convenient opportunity for ExCo members to get together) was held in "fall" in Australia. ExCo members unanimously agreed to hold the ExCo for 2011 at the occasion of ISHW in January 2012.

The quorum (one-half of the members plus one) was satisfied at all ExCo-meetings. Russian representatives were absent from the 39th to the 43rd ExCo. On these occasions, the minutes were sent to them by e-mail, and their consent was obtained to reach unanimous agreement for important issues.

Now, two new Russian representatives, Prof. Boris Kuteev (National Research Center, Kurchatov Institute) and Prof. Viacheslav Ivanov (Prokhorov General Physics Institute of Russian Academy of Sciences (GPI RAS)) were endorsed by ROSATOM, and regular communications with Russia has been restored. Also, in October 2015, the European Commission nominated Lars-Goran Eriksson as an Euratom observer to the SH-IA ExCo.

4.3 Annual Report

The annual report is comprehensive and consists of an executive summary, the report on the CWGM (every year) and the ISHW in the year it was held, as well as the status of domestic and international collaborations, along with the detailed minute of the ExCo-meeting. It has been submitted to the IEA in a timely and complete manner every year. It is also publically available through the SH-IA website, http://iea-shc.nifs.ac.jp/annual_report.html (available are those from 2005 up to 2014). The IA delegate (chair or the substitute) has attended the FPCC every year to present the IA achievements/plans, and to have discussions with representatives from wide-range IAs.

4.4 IEA Framework and IA Legal Document

The IEA Framework for International Energy Technology is available as an appendix to the IA legal document. The IA legal document is also publically available at the IA website.

4.5 Input to IEA Secretariat activities

Energy Technology Initiative: The IA has contributed to editions

- 2013 (p.50: Densities, dynamics and 3-D physics), and
- 2015 (p.61: Super-dense cores and 3-D computations).

Testimonials for commemorating the 40th anniversary of the creation of the Implementing Agreement (IA) mechanism:

- CIEMAT, Spain

  "*The development of the stellarator as a concept for the steady state fusion power plant encompasses two thirds of the Spanish effort in Fusion research. The Implementing Agreement has been the basis of our international collaboration in this area and it has enriched our national research*

programme, leveraging experimental and theoretical capabilities and promoting scientific mobility."
Joaquin Sánchez, Director, CIEMAT National Fusion Laboratory, Madrid, Spain.

- IPP-Greifswald, Germany
  "The optimized stellarator Wendelstein 7-X is one of the most prominent fusion experiments worldwide. Its objective is to demonstrate power plant capability of the stellarator concept. Strong international support was and will continue to be essential for its success. The Implementing Agreement facilitates this support by providing an effective framework for the global exchange of expertise and personnel. It is therefore an indispensable asset for international scale projects such as Wendelstein 7-X."
  Robert Wolf, Director at the Max-Planck-Institute for Plasma Physics, Greifswald, Germany
- NIFS, Japan
  From 1992, the National Institute for Fusion Science (NIFS) has been a leading member of the implementing agreement for co-operation in development of the Stellarator-Heliotron concept for realizing fusion energy. It has provided sound basis for long-standing international collaborations, to establish world-standard plasma confinement and profile database, and to leverage scientific and technological achievements of the world-largest superconducting fusion experiment, Large Helical Device (LHD). Now, IA-bridging steady-state operations co-ordination group (SSOCG) has been launched and co-chaired by NIFS upon LHD's record-breaking progress on this issue.
  Akio Komori, Director-General, National Institute for Fusion Science, Toki Japan

A delegate from the SH-IA, A. Dinklage, attended the Energy Technology Network meeting on 18 September 2015.

5 Contribution to Technology Evolution / progress

Joint actions such as joint experiments or joint simulation code benchmarking efforts conducted under the auspices of the IA have facilitated the academic understanding and systemization to lead the improvement of the performance of high-temperature plasma confinement.

Some examples for significant publically recognized "success stories" (e.g. cites in scientific journals, awards etc.) are as follows:

- "Research on high-ion-temperature plasmas through the advanced heating methods foreseeing the nuclear fusion", O.Kaneko, Y.Takeiri and M.Osakabe (National Institute for Fusion Science)
- Prizes for Science and Technology, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Japan
- "Flow damping due to the stochastization of the magnetic field" K.Ida, S.Inagaki et al., and the LHD Experiment Group, National Institute for Fusion Science and Kyushu University, Nature Communications (Jan. 8, 2015)

- IEEE Fusion Technology Award 2014 to Felix Schauer, head of the Wendelstein 7-X engineering division, in recognition of his outstanding contributions to fusion research and superconducting magnet technology.
- Overwhelming recognition of the successful construction of the superconducting optimized Stellarator W7-X in international media.
- Mitigation of NBI-driven Alfvén eigenmodes by electron cyclotron heating in the TJ-II stellarator, K. Nagaoka, T. Ido, E. Ascasíbar, T. Estrada et al., 2013 Nucl. Fusion 53 072004.
- Collaboration between groups under the Stellarator/Heliotron and Reversed Field Pinch Implementing Agreements resulted in a new understanding of the formation of a helical state in the Padua RFX device. Minimally Constrained Model of Self-Organized Helical States in Reversed-Field Pinches – G. Dennis G, S. Hudson, D. Terranova, et al., Physical Review Letters 111 (2013) 055003.
- Small size RF antenna (14x14 cm^2) with operational frequency 135 MHz and RF power of a few kW has been installed into U-2M vacuum chamber. It was shown that the antenna is able to produce and maintain plasma with parameters suitable for providing wall conditioning in a wide range of magnetic field (0.1-1.0 kG). V.E. Moiseenko, V.L. Berezhnyj, V.N. Bondarenko et al. *Nucl. Fusion* 51, 083036 (2011).
- A simple method has been suggested and realized for suppression of runaway electrons appearance during ramp up/down stages of magnetic field at torsatrons Uragan-2M and Uragan-3M; the results were explained theoretically. V.E.Moiseenko, V.B.Korovin, I.K.Tarasov et al. *Letters to J. Phys. Reports,* 40, #15, pp.80-96, 2014.

Also, the list of the highlighted scientific/technological achievements of SH-IA over the past five years can be given as follows:

- At the Large Helical Device, National Institute for Fusion Science, Japan, the own world record of the total injected energy onto the steady-state plasmas was broken (also one of highlights in SSOCG activity)
- Successful commissioning of Wendelstein 7-X and first measurement of closed flux surfaces, proving the precise alignment of the superconducting magnet system.
- Comprehensive approach to the problem of MHD stability. MHD stability was analyzed with the help of thee-dimensional numerical code and analytically. The results of calculations are in reasonable agreement with experimental data. M.I Mikhailov (Kurchatov institute), S.V. Shchepetov (GPI), C. Nührenberg and J. Nührenberg (IPP), L-2M Experimental Team, Prokhorov Institute of General Physics of the Russian Academy of Sciences, Plasma Physics Reports (2013-2015).
- Prepare the physics basis for controlling fast particles (joint NIFS/Japan-CIEMAT / Spain collaboration): The mitigation effect of electron resonance cyclotron heating on fast particle driven modes reported in TJ-II stellarator suggests an attractive avenue for a possible control tool in reactor relevant conditions...
- Improving confidence in impurity transport predictions (Joint IPP/Germany – CIEMAT/Spain collaboration): Direct experimental evidence of plasma potential

variation on magnetic flux surfaces in the TJ-II stellarator consistent with neoclassical simulations.

- Core plasma fueling experiments (Joint ORNL/US – CIEMAT / Spain): Successful core plasma fuelling experiments using a cryogenic pellet injector system and associated diagnostics in the TJ-II stellarator.
- New gyrotron complex was installed and tested for L-2M stellarator (Prokhorov Institute of General Physics of RAS). Possible plasma effects were calculated and predicted.
- In a multilateral collaboration, Australian data mining techniques have been successfully applied to four stellarator/heliotron experiments. This work will feed into the Stellarator/Heliotron Coordinated Working Group databases...
- (Ukraine) In cooperation with ITP TU-Graz (Austria), IPP Greifswald and IPP Garching (Germany) the codes NEO, NEO-2, NEO-MC have been benchmarked within the International Collaboration on Neoclassical Transport in Stellarators against other solvers, and the NEO-2 version was applied for modelling of some effects in Wendelstein-7X and ASDEX-Upgrade.
- (Ukraine) It was found that the transition to regime of better plasma confinement in Uragan-3M correlates with a short-time ejection from plasma confinement volume of high energy ions. V.V. Chechkin, I.M. Pankratov, L.I. Grigor'eva et al. *Problems Atomic Sci. Technol., series "Plasma Physics"*, No. 6 (82) 2012, pp. 114-116.
- (Ukraine) The first plasma experimental data were obtained demonstrating the possibility to have a combined stellarator-mirror configuration in torsatron Uragan-2M. These experiments were carried out after such feasibility was proven by calculations and by measuring magnetic surfaces via electron-beam-luminescent-rod-technique.
- (Ukraine) The conditions for excitation of quasi-coherent fluctuations in the frequency range 20-400 kHz in Alfvén-wave-heated plasmas of the U-3M torsatron were studied; appearance of modes correlates with the presence of both suprathermal electrons and high-energy ions in the plasma body.

- (Ukraine) It was shown that runaway electrons are possible trigger for enhancement of MHD plasma activity and fast changes in runaway beam behavior in EAST tokamak (I.Pankratov, R.Zhou, L.Hu, 2015 Phys. of Plasmas, 22, 072115).

6 Policy Relevance

The activities conducted in the SH-IA have been well communicated to policy makers in the participating countries.

- Australia
  The Australian representative reports to Government on Implementing Agreement presentations to the Fusion Power Coordinating Committee.
- Europe
  The European Roadmap to the Realization of Fusion Energy (2013) quotes as one of eight missions to bring the stellarator line to maturity, while focusing on the optimized

Helias line. The Roadmap supports the international collaboration on other stellarator lines which are mainly pursued under the umbrella of the Implementing Agreement.

- Europe
  The EUROfusion work plan for the implementation of the Fusion Roadmap in 2014-2018 includes two specific stellarator work packages on the "Preparation and Exploitation of W7-X Campaigns (WPS1)" and "Stellarator optimisation: Theory Development, Modelling and Engineering (WPS2"),
- Germany
  Fusion research in general and specifically research on the Stellarator-Heliotron concept was included in the 6. Energy Research Program of the Federal Government of Germany (Research for an environmentally sound, reliable and affordable energy supply, Federal Ministry of Economics and Technology, 2011).
- Japan
  Annual report and minutes of ExCo have been submitted to the Ministry of Education, Culture, Sports, Science and Technology (MEXT). These have been taken into account in policy making, in particular on Heliotron research.
- Russia
  Annual reports are sent to Presidium of Russian Academy of Sciences, the latter submit the Joint report to the related ministries. These materials are taken into account in scientific policy making.
- Spain
  The EU stellarator program is focused on the optimized Helias line as pointed in the EU Fusion Roadmap to the realization of fusion energy. Work on other stellarator lines is part of international collaboration under the umbrella of the Implementing Agreement.
- USA
  The US Department of Energy has greatly raised the awareness for Stellarator-Heliotron research by providing grants to US-Universities, earmarked for the collaboration on the superconducting stellarator experiments LHD and W7-X, and through substantial hardware contributions for W7-X.

6.1 Relevance to IEA analysis

The SH-IA has contributed continuously on IEA analysis (upon request from the Secretariat). (cf. Sec. 4.5). Progress on scientific understandings on the three-dimensional magnetic confinement in Stellarator-Heliotron research were reported and used in the IEA Energy Technology Initiatives (2013), and progress of steady-state operation research in LHD and the advancement of Wendelstein 7-X assembly were reported and used in the IEA Energy Technology Initiatives (2015).

6.2 Relevance to other high level events

Below is the list of Implementing Agreement's contributions to high level events over the past five years.

- Japan (NIFS and universities) - Spain (CIEMAT) collaboration, a part of the SH-IA, was picked up on the agenda in the 1st (Jul. 2012, Madrid) and 2nd (September 2014, Tokyo) Japan-Spain Joint Committee on Science and Technology Cooperation, as in http://www.mofa.go.jp/page1e_000029.html

- Japan (NIFS and universities) - Germany (Max-Planck Institute for Plasma Physics), a part of the SH-IA was picked up on the agenda of the 21st Meeting of the Japan-German Joint Committee on Cooperation in Science and Technology (March 2013, Tokyo).

7 Contribution to Environmental Protection

Fusion research, including the Stellarator-Heliotron concept, has been still under development and is still distant to a fusion power plant. However, in the long-term, the SH-IA indeed expects to make a significant contribution to environmental protection, through the realization of fusion power plant.

8 Contribution to Information Dissemination

During the past five years, the SH-IA tried to develop its information dissemination as follows:

- Outreach of three-dimensional research conducted in SH-IA to ITPA (International Tokamak Physics Activity) was made several times to introduce and facilitate the viewpoints of "3D physics" in tokamaks.
- The established strong link between SH-IA and SSOCG has been a good example for communication between experts on steady-state plasma confinement research, and similarly the connections that were made between the SH-IA and the RFP-IA, resulting in a joint conference, and collaborations on the ‘helical state’.

The formation of links between the SH-IA Coordinated Working Groups and all ITPA Activities are detailed in Section 3.2

The SH-IA website, http://iea-shc.nifs.ac.jp/, has been continuously updated. The website is currently hosted by NIFS. The most recent update was made on 17 April 2015. Other regular updates include the upload of the annual report and reports on the CWGM. Along with the transfer of the chairmanship of the SH-IA, the website will be hosted by IPP Greifswald.

9 Outreach to IEA non-Member Countries

Ukraine and Russia have been long standing members of the Implementing agreement and were part of numerous fruitful collaborations. With the appointment of two new Russian representatives, the Russian Federation has renewed their commitment to the Implementing agreement.

10 Added Values

See. Sec. 8 for enhanced interactions with other expert groups.

11 References

Contracting Parties, SH-IA legal text (Written Agreement), Annual Report (from 2005 to 2014, including End of Term Report 2005-2009 for the last extension), Stellarator news (community journal), information on CWGM and ISHW, are all available at the SH-IA website, http://iea-shc.nifs.ac.jp/.

12 List of SH-IA Joint Publications, presentations in major international conferences (2010-2015)

Authors	Title	Journal	Vol.	Year	Paper #	Page
Akiyama, T. et al., ,	Status of a stellarator/heliotron H-mode database	Contributions to Plasma Physics	50	2010		590
Bustos, A., et al.,	Impact of 3D features on ion collisional transport in ITER	Nuclear Fusion	50	2010	125007	
Cooper, W.A., et al.,	Drift stabilisation of ballooning modes in an inward-shifted LHD configuration	Contributions to Plasma Physics	50	2010		713
Darrowa, D.S., et al.,	Measurements of beam ion loss from the Compact Helical System	Nuclear Fusion	50	2010	105009	
Felici, F., et al.,	Feedback control of ECRH polarization on LHD	Nuclear Fusion	50	2010	105003	
Garcia-Regana, J.M., et al.,	Comparison of different models for EBCD calculation in the TJ-II Stellarator	Plasma Physics and Controlled Fusion	52	2010	65007	
Goncharov, P.R., et al.,	Analytical and semianalytical solutions to the kinetic equation with Coulomb collision term and a monoenergetic source function	Physics of Plasmas	17	2010	112313	
Kernbichler, W., et al.,	Generalized Spitzer function with finite collisionality in toroidal plasmas	Contributions to Plasma Physics	50	2010		761
Kumar, S.T.A., et al.,	Core magnetic islands and plasma confinement in the H-1NF heliac	Physics of Plasmas	17	2010	82503	
Melnikov, A.V., et al.,	Internal measurements of Alfvén eigenmodes with Heavy ion beam probing in toroidal plasmas	Nuclear Fusion	50	2010	84023	
Murakami, S., et al.,	Optimization study of ICRF heating in the LHD and HSX configurations	Contributions to Plasma Physics	50	2010		546
Nagasaki, K., et al.,	Effect of magnetic field ripple on electron cyclotron current drive in Heliotron J	Nuclear Fusion	50	2010	25003	
Nagasaki, K., et al.,	ECCD experiments using the upgraded launching system in Heliotron J	Contributions to Plasma Physics	50	2010		656
Nishimura, S., et al.,	A convergence study for the Laguerre expansion in the moment equation method for neoclassical transport in general toroidal plasmas	Physics of Plasmas	17	2010	82510	
Pustovitov, V.D.	Diamagnetic measurements and plasma energy in toroidal systems	Plasma Physics and Controlled Fusion	52	2010	85005	
Pustovitov, V.D.	Anisotropic pressure effects on plasma equilibrium in toroidal systems	Plasma Physics and Controlled Fusion	52	2010	65001	
Ramisch, M., et al.,	Investigation of turbulent transport and shear flows in the edge of toroidal plasmas	Contributions to Plasma Physics	50	2010		718
Tanaka, K., et al.,	Particle transport of LHD	Fusion Science and Technology	58	2010		70
Toi, K., et al.,	MHD modes destabilized by energetic ions on LHD	Fusion Science and Technology	58	2010		186
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