National Institute for Fusion Science (NIFS)
National Institutes of Natural Sciences (NINS)

External Peer Review Reports in FY2013

March, 2014

External Peer Review Committee, NIFS Advisory Committee
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Chapter 1 Background

The National Institute for Fusion Science (hereafter as NIFS) was established in 1989 as an inter-university research institute, with the Large Helical Device (hereafter as LHD) as its principal experimental device, in order to promote fusion research in universities. The planned LHD, bearing the fusion community’s consensus and expectations, and characterized by its superconducting Heliotron-type magnetic confinement system, emerged from an idea unique to Japan and has been independently conceived and developed in Japan. Together with generating high-performance helical-type plasmas through its high-power heating system, the LHD is advancing experimental research that aims to clarify physical and engineering issues that stare at the realization of a toroidal magnetic field confinement fusion reactor. On the other hand, parallel to this, utilizing large-scale simulations is essential in analyzing the complexities of fusion plasma. At NIFS, having introduced the newest supercomputer and made it available for collaborative use to fusion theory researchers throughout Japan, we are moving forward with leading-edge research.

Recently, there have been changes to the system for domestic academic research. Since 2004 NIFS has been an institution within the National Institutes of Natural Sciences (hereafter as NINS), and has advanced collaborative use and collaborative research. Since being incorporated, NINS has introduced six-year mid-term goals and mid-term plans, and a system for undergoing annual evaluations of progress. This annual evaluation focuses primarily upon management and operation, and at NIFS receiving evaluations of research results by researchers outside NIFS was deemed to be important. Under the Advisory Committee, the External Peer Review Committee has been established, and it conducts annual research evaluations. The items to be evaluated are decided upon at the Advisory Committee. Adding external members of the Advisory Committee and experts to the Review Committee, the Committee members will conduct evaluations. The Review Committee reports its results to the Advisory Committee, and NIFS, respecting the results of the evaluation, utilizes the results in improving research activities from the next year.

At NIFS, from 2010 began the second period for mid-term goals, and in order to strengthen further the unifying core of NIFS as the Center of Excellence in the plasma and fusion research fields, we composed research projects for the three fields of the LHD, theory simulation, and fusion engineering, and initiated research planning for combining the research results from these fields in moving toward realization of the fusion reactor. For this reason, in 2010 we undertook a restructuring of the research organization within NIFS. In addition to placing all researchers in one research department, we composed a structure that enables researchers to participate independently in projects. Through these changes, coordination among the LHD, theory simulation, and fusion
engineering projects became easier, and we have become able to respond to new topics in a timely manner.

In the Advisory Committee, in order to confirm the results of the project system, first, in JFY2011, we implemented an external peer review of the LHD Project and in 2012 of the Numerical Simulation Research Project. Then, in this current year (2013) we decided to implement an external peer review of the Fusion Engineering Research Project (hereafter as FERP), which is in the fusion engineering field. We established an External Peer Review Committee that included the nine members of the Advisory Committee who are not NIFS researchers and the four members from foreign countries, and five other specialists.

In their first meeting held on October 11, 2013, the members discussed the review process and determined the overall objectives and individual items. On November 30, NIFS presented Fusion Engineering Research Project activities in detail using viewgraphs and other materials, and answered the questions from the reviewers. On January 28, 2014, reviewers gathered in subgroups and rated the activities after resolving any outstanding issues. The reviewers then met on February 21 to finalize their review and document this report.

This report consists of three chapters: “Background,” “Reviews and Proposals,” and “In Closing.”

The report will be submitted to the Advisory Committee of NIFS. After gaining the Advisory Committee’s approval, the Director General of NIFS will submit the report to the President of its parental body, NINS. The report will go through NINS to be submitted to the Administrative Council and the Education and Research Council of NINS. After the approval of these councils, this report will be used as an appendix of NINS’s annual reports in “Annual Plan of NINS (JFY2014)” and “Report of Achievements of Business Work in JFY2013” to be submitted to the Ministry of Education, Culture, Sports, Science and Technology. The report will be available to public on the web and in print.

In the evaluation of the Fusion Engineering Research Project, in the mid-term planning stipulated by NINS the basis of the evaluation is the degree of completion of the Fusion Engineering Research Project on which NIFS is advancing, and which has the goals of establishing the fusion reactor design and the engineering base for the reactor, as well as the research standards.

It should be noted that these items of evaluation are based on the proposals from the external evaluation of fusion engineering research, conducted in JFY2009.
1. Whether or not fusion engineering research is developing across the board with the emphasis on helical reactors design
2. Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership in terms of international research
3. Whether or not NIFS continues to develop superconducting coils for fusion reactor development
4. Whether or not efforts are being made to encourage young researchers to participate in the fusion reactor research project
5. Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors

The following is a list of this year’s evaluation items on the Fusion Engineering Research Project:

[1] Establishment of research system and environment
   (1) Whether or not the target of FERP, initiated in JFY2010, is appropriate
   (2) Whether or not the organization of FERP is coincident with its target and properly functioning
   (3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

[2] Research achievements
   Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor
   (1) Helical fusion reactor design
   (2) R&D toward establishment of the engineering basis

[3] Encouragement of joint activities and collaborative research
   (1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes
   (2) Whether or not NIFS is contributing to the development of research at universities
   (3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

[4] Human resources development
   Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

[5] Future plans
   Whether or not the future plan is pointing appropriately toward the medium- to long-term targets
Chapter 2  Reviews and Proposals

Here is a summary of the comments and arguments given by the reviewers. This is followed by proposals which will be important in advancing the FERP research.

2.1  Summary of reviews

[1] Establishment of research system and research environment

(1) Whether or not the target of FERP, initiated in JFY2010, is appropriate

Regarding the important issues of reactor engineering that also are consistent with those for tokamak reactors, as a research center in Japan, together with establishing an engineering base through a helical fusion reactor design and taking into account previous suggestions, NIFS is moving forward with setting objectives while planning the consistency of the reactor design and the engineering bases. We can say that appropriate objectives are being set as objectives for the Fusion Engineering Research Project, and we rate this highly.

On the other hand, as research by NIFS and universities, integration as a complete fusion reactor founded upon academic, elemental research is important. And we hope that while paying attention to complementarity and supplementation with tokamak reactors there will be flexible responses to both long-term objectives and short-term objectives and their feasibility.

(2) Whether or not the organization of FERP is coincident with its target and properly functioning

By shifting to a project system NIFS has become able to promote flexible research activities that can be pushed forward while aiming at organic collaboration with numerous related researchers within NIFS. Further, able to proactively advance collaborative research with universities and other institutions, by forming a domestic center, promoting cooperation across projects, allotting topics within the group, and actively placing young leaders, NIFS is constructing a system that considers the development of human resources. Accordingly, we highly rate this construction of a system that accords with the project's goals and is functioning appropriately.

On the other hand, construction of a system for revising each task and feedback from reactor design to experiments and R&D groups are necessary. Further, we hope for the enhancement of researchers moving forward proactively with fusion engineering.
(3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

Through continuous effort including a large-scale supplementary budget, high-level experimental equipment as well as research tools are available. That an environment in which it is possible to construct an infrastructure for engineering is being appropriately advanced is highly rated.

Hereafter, it will be important that there be a research structure that includes researchers throughout Japan. Utilizing collaborative research, regarding the maintenance and preservation of equipment that span several fields, through maintaining and increasing technical staff we look forward to the optimization of the operation of equipment as assets of the entire fusion community.

[2] Research achievements

Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor

(1) Helical fusion reactor design

In the design of the helical fusion reactor, which is being emphasized in this project, that taking the conceptual design based upon parameters obtained from the LHD as the standard and linking the design to the Numerical Simulation Research Project indicated a way to self-ignition is of great interest. In particular, this is an advanced conceptual design that incorporated issues confined to the helical device and its strong points, such as the divertor configuration with neutron shielding. This conceptual design is of an extremely high level at the global level. It may be said that this, more so than a comparison with tokamak reactors, is of more significance as reactor design research by extracting engineering issues related to helical fusion reactors. Accordingly, advancing the design for the helical fusion reactor and providing high-level results at the international level is extremely highly rated.

By clarifying the process of design changes amid the flow of designs to this point, together with moving forward with establishing the current understandings and issues feedback to the LHD experiments is important. We hope for indications of the direction of engineering research through written descriptions of the detailed examinations of edge plasma modeling, the heat flux to the divertor, and alpha particles, and, further, through evaluation of the calculations obtained from design and measurements obtained from experiments.
(2) R&D toward establishment of the engineering basis

In developing basic equipment in response to the five issues mentioned above, while advancing collaborative research together with outside researchers, research highly rated internationally is being conducted. Further, including the broad linkages with universities and other research institutions, together with the LHD Project and the Numerical Simulation Research Project, NIFS is actively introducing distinctive cutting edge themes. *We highly rate that such research aiming at constructing engineering bases is being conducted, and that researchers are producing research results of high levels internationally.*

From now it may be said that it is necessary to concentrate not only on pioneering and creative research, but also on basic engineering research development and trials and tests. In particular, we look forward to even further advances regarding issues relating to the radiation technologies such as neutrons and tritium necessary for the future fusion reactor, while examining efficient ways of moving forward and planning country-wide linkages within the areas that only NIFS can implement.

[3] Encouragement of joint activities and collaborative research

(1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes

Regarding the diverse research topics relating to reactor engineering, making use of general collaborative research, LHD project collaborative research, and bilateral collaborative research, collaborative research with numerous universities is being organically conducted. Further, regarding international cooperation, such as the Japan-United States collaborative research, the Japan-People's Republic of China collaborative research, and other forms of international cooperation, international collaborations are being undertaken through linkages with universities with NIFS as the core. Through these activities, *we highly rate the gathering of high-level research abilities present at universities and other institutions and advancing collaborative research appropriately as a Center of Excellence.*

In the future, too, aware of the appraisal of the LHD as an international site, including the exchange of researchers, we look forward to the activities as the Center of Excellence of domestic fusion engineering research. In particular, together with strongly advancing collaborative research in fields such as blankets, with which neutrons and tritium are related, we look forward to NIFS’ role as a Center of Excellence with regard to strengthening society’s
acceptance of fusion and the strengthening of safety.

(2) **Whether or not NIFS is contributing to the development of research at universities**

For undertaking collaborative research as well as research cooperation with numerous universities that are linked to fusion engineering, and for contributing to the expansion of the base of fundamental research in engineering, and for the construction and opening of the database of atomic and molecular processes and plasma-wall interaction, we highly rate NIFS for greatly contributing to the development of research at universities that aim at advancing academic research.

In the future, advancing collaborative research on fusion engineering by using the leading edge expert knowledge of researchers at NIFS and utilizing large-scale experiment facilities which are difficult to implement in terms of maintenance, operation, funding, and personnel at the scale of a university laboratory, together with advancing further the germinating and pioneering research at universities, we look forward to the composition of a database that records research results and to the construction of a system that can widely utilize that information.

(3) **Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others**

To assist the ITER project and the BA activities, testing of the superconductor coils and NBI performance is being conducted, which shows NIFS’s contribution to the ITER project and the BA activities by capitalizing upon the special characteristics of NIFS, which is endowed with specialist research groups and large-scale equipment. Further, reactor engineering researchers at NIFS serve at ITER and actively provide technological assistance in the ITER construction and are contributing to and expanding assistance to the ITER project and the BA activities. Moreover, NIFS has a central role in achieving the planning and implementation of the joint Japan-United States TITAN project and in the execution of the current PHENIX project. And including the contributions to the Atoms and Molecules Database (GENIE), NIFS is providing continuous contributions. Thus, we highly rate contributions to the ITER project and the BA activities as well as the linkages and contributions to international activities.

In the future, in the operation and execution of experiments in the LHD device beginning with superconducting coils technology, we look forward to further contributions to the ITER project, including the operation system, the training of operators, the safety system, and others cultivated at NIFS. Further, regarding the BA activities which aimed at a prototype reactor, we anticipate that this Fusion Engineering Research Project, which possesses great technological
strength and abundant knowledge, will contribute greatly to research, including technological development and engineering verification, on a significant scale. Moreover, we look forward to the clarification of the relationship with NIFS’ helical fusion reactor design, and to the positive contributions of the prototype reactor design joint core team.

[4] Human resource development
Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

As a result of the appointment of young researchers as task leaders, brilliant young researchers who will support fusion research are being nurtured, and numerous exceptional papers are being produced. Further, together with the education guidance that is being provided not only for graduate students at Sōkendai but also for graduate students at Japanese universities and post-doctoral researchers, the introduction of super science high schools (SSH), the implementation of summertime experience enrollment to Sokendai and a steady approach that will educate human resources for the future are moving forward. Through these activities, we rate highly these contributions to the nurturing of human resources who can participate internationally and support the long-term development of fusion research.

Regarding the nurturing of human resources, emphasizing the standpoint of general engineering of fusion research, through nurturing broadly human resources that will contribute to developing advanced science and industrial fields through linkages with universities, we greatly look forward to the expansion of the human foundations of fusion research. Further, we strongly hope for the implementation of measures, such as scholarships and the employment of post-doctoral researchers that will seek to increase the research population in fusion. In particular, in the future, it will be necessary to compose a structure for nurturing human resources that follows the roadmap for realizing the fusion reactor and nurturing human resources that support the fusion reactor’s safety, which is imperative. Moreover, we hope that NIFS will aim to compose a structure that will make active participation in ITER and other international programs by young researchers (including university researchers) possible.

For the nurturing of human resources, long-term and strategic approaches and indicators for appropriately evaluating results are necessary, and it should be urged to continuously engage in discussions.

[5] Future plans
Whether or not the future plan is pointing appropriately toward the medium- to long-term targets
Appropriate goal-setting regarding each element of technology development currently being planned is being undertaken, and it may be said that a system for that purpose and equipment enhancement, too, is being maintained satisfactorily. With regard to the goals that have been established, from now, too, the capacity to continue undertaking appropriate research development and system maintenance can be readily expected. Accordingly, the future research plans that aim at goals are appropriate, and we rate highly the future plans which gaze at mid- and long-term prospects.

On the other hand, it is necessary to clarify the specific road map for aiming toward realization of the helical fusion reactor. Moreover, regarding research and development for the blanket, the divertor, and other important equipment that integrate essential technologies, it will be necessary to clarify further the numerical objectives, the research issues, and the perspective on achievement. At the same time, it will be necessary to also engage in technical issues such as fuel supply, assembly, maintenance, and remote handling. In the above project, a plan based upon an international perspective is indispensable.

Moreover, through active contributions to the prototype reactor design core team, it will be necessary to distinguish among similarities, differences and complementarities in tokamaks and the helical system, and to together search for means for development. It will be necessary to go beyond differences in confinement methods and to pursue engineering similarities and universalities, and to evolve from “technology development” to “engineering bases.” We anticipate that accumulating fundamental experimental data obtained from large-scale equipment at NIFS and developing the database further will contribute to establishing specifications and standards for the fusion reactor.

Through such research activities, we look forward to the nurturing of human resources that will become the axis of advances in the ITER project and development of research on the prototype reactor.

### 2.2 Proposals

Here is a summary of recommendations given by the panel to the NIFS Fusion Engineering Project for its future operation.

1. We look forward to the NIFS Fusion Engineering Project strengthening further the linkages between the LHD Project and the Numerical Simulation Research Project, and together with planning refinements in the helical fusion reactor design advances in strengthening collaborative research in the superconducting coils, the divertor, the blanket, and other topics,
fulfilling the role as the Center of Excellence for developing fundamental technologies in the fusion engineering field, and evolving leading technologies that have been developed toward an academic system as engineering.

(2) Nurturing young researchers who will lead the world in the fusion engineering field, including too the ITER project and the BA activities, is an urgent task. We hope that universities and research institutes will construct linkages for realizing new frameworks for the nurturing of human resources and the enhancement of their quality.

(3) We look forward to planning for the introduction of large-size experiment instruments and test equipment in the fusion engineering field, which is difficult at universities, to the preparation of research environments based upon the placement and increase of human resources, and to the construction of their maintenance and management systems, as well as to strongly advancing the efficient application through collaborative use and research by universities and research institutes.

(4) We look forward to the utilization of the technological results and the engineering expertise that have been cultivated at NIFS, active participation in the ITER project and the BA activities, as well as the accumulation of results and knowledge, the standardization of the fusion reactor through the database, and contributions to the formation of standards.
Chapter 3  In Closing

At NIFS, from 2010 the second period for mid-term goals began, and in order to strengthen further the unifying core of NIFS as the Center of Excellence in the plasma and fusion research fields, we composed research projects for the three LHD, theory simulation, and fusion engineering fields, and initiated research planning for combining the research results from these fields in moving toward realization of the fusion reactor. For this reason, in 2010 a restructuring of the research organization within NIFS was undertaken. All researchers were placed in one research department, and a structure was composed that enables researchers to participate independently in projects. Through these changes, linkages among the LHD, theory simulation, and fusion engineering projects are advanced, and timely responses to new topics are anticipated.

In the Advisory Committee, in order to confirm the results of the project system, first, in 2011, we implemented an external peer review of the LHD project and in 2012 the external peer review of the Numerical Simulation Research Project. Then, in this current year (2013) we decided to implement an external peer review of the Fusion Engineering Research Project, which is in the fusion engineering field. We established an External Peer Review Committee that includes the nine members of the Advisory Committee who are not NIFS researchers and the four members from foreign countries, and five other specialists.

At the first meeting of the External Peer Review Committee, which was held on October 11, 2013, we discussed how to advance with this year’s external peer review. It was decided to evaluate the points below.

[1] Establishment of research system and environment
   (1) Whether or not the target of FERP, initiated in JFY2010, is appropriate
   (2) Whether or not the organization of FERP is coincident with its target and properly functioning
   (3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

[2] Research achievements
   Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor
   (1) Helical fusion reactor design
   (2) R&D toward establishment of the engineering basis
[3] Encouragement of joint activities and collaborative research

(1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes
(2) Whether or not NIFS is contributing to the development of research at universities
(3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

[4] Human resources development

Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

[5] Future plans

Whether or not the future plan is pointing appropriately toward the medium- to long-term targets

At their second meeting held on November 30, 2013, the panel was provided by the institute with detailed information on the FERP activities along with the items above. On January 28, 2014, the reviewers gathered in subdivided groups and moved forward with the evaluation process. After all the subgroups completed their proposals, the panel finalized its work in a report at its third meeting held on February 21.

As results of this external peer review evaluation of the Fusion Engineering Research Project, regarding all of the items above, it has been concluded that in general they can be highly rated. In particular, regarding research results relating to the helical fusion reactor design, this advanced conceptual design incorporated strong points and issues unique to the helical system, and can be extremely highly rated. Further, the setting of goals for the Fusion Engineering Research Project and the propulsion system can be said to be appropriate and functioning organically, and this too can be highly rated. Moreover, that high-level experimental instruments and research equipment have been introduced and a research environment is being provided, and that as a Center of Excellence in this field NIFS is contributing to research development at universities too can be highly rated. On the other hand, regarding research aimed at constructing a base for engineering, linkages with the ITER project and the BA activities, and the nurturing of human resources, the constant visibility of effort can be highly rated, though we look forward to still further development. Regarding future plans, there is sound planning, which was well and carefully undertaken based upon achievements to date, and this too can be highly rated. However, we look forward to efforts aimed at advancing academic research that deepens further from “technology development” to “engineering bases.”

Still further, adding to these evaluation results, there are demands for the establishment of a system
regarding the efficient application of the experimental instruments and research equipment already provided and for construction of a new framework for nurturing young researchers who will lead the world in the fusion engineering field, and we look forward to the realization of these demands as links with the fusion community.

To conclude, we have summarized below final comments regarding future ways of moving the Fusion Engineering Research Project forward.

(1) We look forward to the NIFS Fusion Engineering Project strengthening further the linkages between the LHD Project and the Numerical Simulation Research Project, and together with planning refinements in the helical fusion reactor design advances in strengthening collaborative research in the superconducting coils, the divertor, the blanket, and other topics, fulfilling the role as the Center of Excellence for developing fundamental technologies in the fusion engineering field, and evolving leading technologies that have been developed toward an academic system as engineering.

(2) Nurturing young researchers who will lead the world in the fusion engineering field, including too the ITER project and the BA activities, is an urgent task. We hope that universities and research institutes will construct linkages for realizing new frameworks for the nurturing of human resources and the enhancement of their quality.

(3) We look forward to planning for the introduction of large-size experiment instruments and test equipment in the fusion engineering field, which is difficult at universities, to the preparation of research environments based upon the placement and increase of human resources, and to the construction of their maintenance and management systems, as well as to strongly advancing the efficient application through collaborative use and research by universities and research institutes.

(4) We look forward to the utilization of the technological results and the engineering expertise that have been cultivated at NIFS, active participation in the ITER project and the BA activities, as well as the accumulation of results and knowledge, the standardization of the fusion reactor through the database, and contributions to the formation of standards.

Based upon these suggestions, one may say that steadily advancing the Fusion Engineering Research Project in the future will greatly contribute to the strengthening of the academic base and the research development systems in the fusion field.
Documents

2013 External Peer Review Presentation Materials

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<th>Year</th>
<th>Event Description</th>
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<tbody>
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<td>1989</td>
<td>NIFS was established</td>
<td>Safety and Environmental Research Center (Materials, Blanket) 30kg Vanadium ingot (NIFS-HEAT-1) production.</td>
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<td>1990</td>
<td>BA-IFMIF/EVEDA Joint research was started</td>
<td>Production of particle dispersion strengthened vanadium.</td>
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<td>1991</td>
<td>Post-CUP was started</td>
<td>Liquid lithium loop production and operation.</td>
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<td>Establishment of Research System and Environment</td>
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<td>Research Division established</td>
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Points of Evaluation

[1] Establishment of Research System and Environment
研究環境の整備

[2] Research Achievements - Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor
研究成果 ～ハリカル型核融合炉の研究を進めることにより、国際的に高いレベルの成果を上げているか

[3] Encouragement of Joint Activities and Collaborative Research
共同利用・共同研究の推進

[4] Human Resource Development - Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study
人材育成 ～核融合研究の長期的な発展を支える国際的に活躍できる人材の育成に貢献しているか

[5] Future Plans - Whether or not the future plan is appropriately pointing at the medium-to long-term target
将来計画 ～目標に向けた今後の研究計画は適切か。特に、中長期的展望を見据えたものとなっているか
[1] Establishment of Research System and Environment

(1-1) Whether or not the target of FERP, initiated in FY2010, is appropriate

平成22年度にプロジェクトとして位置付けられた核融合工学研究プロジェクトの目標設定は適切か

(1-2) Whether or not the organization of FERP is coincident with its target and properly functioning?

推進体制は目標に合致し、適切に機能しているか

(1-3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

工学基盤の構築を可能とする研究環境の整備は適切に進められているか

---

(1-1) Target of FERP

FERP has been launched since 2010

With the target of

Promotion of conceptual and baseline designs toward realization of a steady-state helical fusion reactor and construction of engineering basis that enables real-scale and real-environment R&D

定常ヘリカル型核融合実現に向けての概念及び基本設計の推進と、実規模・実環境試験を可能にする基幹工学基盤の構築

Two keywords:

✓ Conceptual design of helical reactor ➔ Reactor Design
✓ Construction of engineering basis ➔ R&D

Any researcher can participate in FERP, although the main body is the former ‘Fusion Engineering Research Center (FERC)’
Objectives and plans for the 2nd mid-term

Objectives to increase the quality of research and education in NINS

“As one of the nation’s centers of excellence, NIFS intends to organize the academic activities concerning fusion sciences and related fields at universities and other research institutes. To achieve controlled thermonuclear fusion, meant to be environmentally safe, NIFS will promote all fusion-related research collaborations, including internationally coordinated activities towards nuclear fusion experiments, based on the use of large experimental devices and computers.”

Action to achieve the objectives

Promotion of PROJECTs in NIFS

“Research should be conducted for the development of blankets and superconducting coils along with efficient reactor design activities, intending the establishment of academic fundamentals.”

FERP as a ‘PROJECT’ of NIFS

Roadmap of FERP

Objectives

- Increase the quality of research and education in NINS
- Promote all fusion-related research collaborations
- Intend the establishment of academic fundamentals

Action to Achieve Objectives

- Development of blankets and superconducting coils
- Efficient reactor design activities
- Establishment of academic fundamentals

Promotion of PROJECTs in NIFS

FERP (Fusion Engineering Research Project)

LHD (Large Helical Device Project)

NSRP (Num. Sim. Res. Project)

2010

- Step by step advancement of reactor design
- Conceptual design

2017

- Establishment of Engineering base
- Full-scale, full condition engineering validation

2022

- Advanced fundamental academic research

Collaborative research with universities and institutes

ITER/BA activity: DEMO R&D, conceptual design, JT-60SA, IFIM/EVEDA
### Tasks for FERP (1)

#### Mid-Goal

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid Term Goal 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superconducting Magnet Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Achievement</td>
<td>Next Move</td>
</tr>
<tr>
<td></td>
<td>Collaboration</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### International Conference: 27, Publications: 7

- Red: Reactor Design
- Green: R&D

### Mid-Term Schedule

- The work plan was already determined at the start-up phase of FERP.

---

International conferences concerned
### Tasks for FERP (2)

**In-Vessel Component Group -1-**

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blanket design</td>
<td>Material selection for long-term performance retention</td>
<td>Property evaluation of electron beam welding section / Dissimilar welding test / Fabrication of Y doped high Cr alloy</td>
<td>Investigation of irradiation effects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blanket design</td>
<td>Performance enhancement of vanadium alloy</td>
<td>No performance degradation in 1α/ODS at &gt;900°C / Fabrication of high Cr ODS</td>
<td>Optimization of heat treatment process / Improvement test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blanket design</td>
<td>Performance enhancement of low activation ferritic steel</td>
<td>Multilayer oxide coating and nitride coating by large area coating techniques / Hydrogen permeation reduction &lt;2 μm</td>
<td>Irradiation test / Comparison of pg–ODS and 14C–ODS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blanket design</td>
<td>Development of large area ceramic coating</td>
<td>Accurate evaluation of hydrogen solubility and diffusivity in Li–Pb / Construction of LiPb corrosion test loop with ferritic steel</td>
<td>Optimization of coating fabrication process / Coating test on tube and duct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blanket design</td>
<td>Acquisition of chemical property of coolant</td>
<td>Evaluation of fuel breeding and shielding performance by OD neutronics calculation</td>
<td>Understanding of hydrogen transport in LiPb flow / Acquisition of corrosion data in LiPb flow with temperature gradient</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blanket design</td>
<td>Blanket design for FFHR</td>
<td>Vacuum Shield</td>
<td>Blanket design</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat, hydrogen isotopes recovery system</td>
<td>Data acquisition and modeling of hydrogen isotope transport</td>
<td>Design and construction of Tokai loop Oshin’s / Successful circulation control</td>
<td>Kyoto Univ., Kyoto Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat, hydrogen isotopes recovery system</td>
<td>Data acquisition and modeling of hydrogen isotope transport</td>
<td>Development of hydrogen recovery tube</td>
<td>Yokosaki Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>First wall</td>
<td>Data acquisition and modeling of hydrogen isotope transport</td>
<td>Data acquisition of plasma driven and gas driven hydrogen permeation-2</td>
<td>Yokosaki Univ.</td>
</tr>
</tbody>
</table>

### Tasks for FERP (3)

**In-Vessel Component Group -2-**

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuume vessel</td>
<td>Vacuum vessel</td>
<td>Manufacture of a sector mock up</td>
<td>Analysis / design using numerical equations / Structure of radial build component / Access ports with large aperture</td>
<td>Optimization in accordance with maintenance scenario</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td>Vacuum vessel</td>
<td>Manufacture of a divertor module</td>
<td>R&amp;D of short sample made of W and RAFM pipe / Examination of specifications and arrangements</td>
<td>Test under high heat load</td>
<td>Obayashi Univ. of Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote maintenance</td>
<td>Demonstration of maintenance process</td>
<td>Research of maintenance condition and machinery / Development of autonomous mobile robot</td>
<td>JAEA</td>
</tr>
<tr>
<td>Divertor</td>
<td>Divertor</td>
<td>Manufacture of a divertor module</td>
<td>R&amp;D of short sample made of W and RAFM pipe</td>
<td>Test under high heat load</td>
<td>Obayashi Univ. of Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote maintenance</td>
<td>Demonstration of maintenance process</td>
<td>Research of maintenance condition and machinery / Development of autonomous mobile robot</td>
<td>JAEA</td>
</tr>
</tbody>
</table>

**Red: Reactor Design**

**Green: R&D**

*(International conference: 67, Publications: 119)*
### Tasks for FERP (4)

#### Reactor System Design Group -1-

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Design Integration]</td>
<td>Task setting and project management</td>
<td>Preparation of conceptual design report of helical reactor FMR, etc.</td>
<td>Proceeded with the conceptual design</td>
<td>Proceeded with the conceptual design</td>
<td>JAERI (BA-10DA) Universities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planning of real-scale and real-environment test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integrate report on FMR as conceptual design was published</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Managed a large supplementary budget</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Conceptual design of helical fusion reactor</td>
<td>Development of conceptual and feasible design concept</td>
<td>Development of conceptual design code</td>
<td>Feedback of the result of detailed analysis</td>
<td>JAERI (BA-10DA) Universities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of conceptual design</td>
<td>Development of B, Y, D-shape design of in-vessel components</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(Building Layout)</strong></td>
<td>Layout design and construction process</td>
<td>Site layout design</td>
<td>Listing of buildings</td>
<td>Determine the location of buildings</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Establishment of concept of construction process</td>
<td>Listing of necessary task at the construction</td>
<td>Estimation of the amount of time of each task</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design report based on steam turbine generator</td>
<td>Conceptual design based on steam turbine generator</td>
<td>Adjustment of thermal source and heat exchanger design</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimation of power flow and design of start up procedure</td>
<td>Conceptual design of start up scenario and dc power system of SC coils</td>
<td>Feed back of the design results of other components</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td>Reactor building design</td>
<td>Design of reactor building in NIFS</td>
<td>Evaluation of the floor space</td>
<td>Layout design of equipment in the building</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design of reactor building</td>
<td>Evaluation of leakage field profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transmission and hydrogen production</td>
<td>Integration design of hydrogen production plant</td>
<td>Conceptual design of hydrogen production was published</td>
<td>Component design of hydrogen production plant</td>
<td>JAERI (BA-10DA) Universities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Development of MgB2 cable for SC transmission line</td>
<td>Conceptual design of hybrid energy transmission line was published</td>
<td>Development of MgB2 cable with high current capacity</td>
<td>JAERI (BA-10DA) Universities</td>
</tr>
</tbody>
</table>

### Tasks for FERP (5)

#### Reactor System Design Group -2-

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Tritium)</td>
<td>Tritium fuel balance</td>
<td>Demonstration of tritium inventory, particle balance and required tritium decontamination factor (DF)</td>
<td>Demonstration of tritium fuel balance using simple mass balance model and estimation of required throughput and DF, etc.</td>
<td>Verification and validation of integrated tritium removal system code using middle scale tritium removal system</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration of tritium inventory, particle balance and required tritium decontamination factor (DF)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Tritium safety handling</td>
<td>Development of high-throughput (&gt;300 m3/h) tritium removal system and its system code</td>
<td>Demonstration of preliminary integrated tritium removal system code combined with catalyst and membrane separator</td>
<td>Development of simple tritium decontamination system by atmospheric pressure plasma</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration of tritium inventory, particle balance and required tritium decontamination factor (DF)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Tritium decontamination</td>
<td>Verification of tritium decontamination in/on the metal materials</td>
<td>Understanding of hydrogen isotope behaviors in/on a stainless steel by glow discharge cleaning</td>
<td>Development of simple tritium decontamination system by atmospheric pressure plasma</td>
<td>Univ. of Toyama (HRC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration of tritium decontamination in/on the metal materials</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Tritium monitoring</td>
<td>Demonstration of low level tritium monitoring : 200 Bq/m3 of 3H- and 40 Bq/m3 of water at 600 min.</td>
<td>Tritium gas: performance optimization</td>
<td>Tritium measurement and demonstration of 3H ~ 20 Bq/m3</td>
<td>Kyoto Univ. (HRC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstration of low level tritium monitoring : 200 Bq/m3 of 3H- and 40 Bq/m3 of water at 600 min.</td>
<td>Tritated water : few Bq/m3 at 180 min.</td>
<td>Shorter counting time toward 6 Bq/m3-water @500 min.</td>
<td>Nagoya Univ.</td>
</tr>
<tr>
<td>(Operation Control)</td>
<td>Safety analysis and control system</td>
<td>Conduct safety analysis</td>
<td>Review of safety analysis</td>
<td>Preparation of safety analysis code</td>
<td>Osaka Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptual design of control system</td>
<td>Consideration of safer blanket design</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Burn control</td>
<td>Establishment of plasma operation scenario</td>
<td>Demonstration of ignition access by quasi-3D calculation</td>
<td>Detailed physics analysis of the simulated profiles</td>
<td>Osaka Univ.</td>
</tr>
</tbody>
</table>
Tasks for FERP (6)

Selector

Red: Reactor Design
Green: R&D

Reactor System Design Group -3-
(International conference: 56, Publications: 81)

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Core Plasma) Plasma experiment</td>
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<td></td>
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<td></td>
<td>Sub-ignition in FFHR-dSB with $T_{\text{i}} = 3$ GW @ $f_s = 1$, $\beta_i = 1$, $\beta_n = 30 %$</td>
<td>Sub-ignition in FFHR-dSB with $T_{\text{i}} = 3$ GW @ $f_s = 1$, $\beta_i = 1$, $\beta_n = 30 %$</td>
<td>Analysis of the profiles during the start-up and sustainment phases predicted by HELIOSCOPE</td>
</tr>
<tr>
<td>MHD equilibrium and stability</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Analysis of the profiles during the start-up and sustainment phases predicted by HELIOSCOPE</td>
<td>(same as above)</td>
<td>LHD NSRP</td>
</tr>
<tr>
<td>Neoclassical transport</td>
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<td></td>
<td></td>
<td></td>
<td>(same as above)</td>
<td>Kyoto Univ. LHD NSRP</td>
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<tr>
<td>Alpha heating</td>
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<td></td>
<td>(same as above)</td>
<td>Kyoto Univ. LHD NSRP</td>
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<tr>
<td>Anomalous transport</td>
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<td></td>
<td>(same as above)</td>
<td>KYR</td>
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<tr>
<td>Plasma operation scenario</td>
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</table>

Tasks for FERP (7)

Selector

Red: Reactor Design
Green: R&D

Reactor System Design Group -4-
(International conference: 56, Publications: 81)

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Plasma Heating) NBI</td>
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<td>ECRH</td>
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<tr>
<td>(Fueling) P</td>
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</tbody>
</table>
Tasks for FERP (8)

Reactor System Design Group -5-

<table>
<thead>
<tr>
<th>Task</th>
<th>Subject</th>
<th>Mid-Term Goal</th>
<th>Achievement</th>
<th>Next Move</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Diagnostics)</td>
<td>Investigation of available diagnostics</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Neutron diagnostics</td>
<td>Design of the device</td>
<td>Feasibility check of existing neutron flux monitor and spectrometer for DEMO</td>
<td></td>
<td></td>
<td>Tokyo Inst. of Tech. JAEA</td>
</tr>
<tr>
<td>Spectroscopic diagnostics</td>
<td>Design of the device</td>
<td>Particle source profile measurement with single line-of-sight</td>
<td></td>
<td></td>
<td>Kyoto Univ. Shinshu Univ.</td>
</tr>
<tr>
<td>Interferometer / reflectometer</td>
<td>Design of the device</td>
<td>Measurement test with a prototype (CO2 laser) system has begun on LHD</td>
<td></td>
<td></td>
<td>Kyoto Univ. Shimane Univ. Chubu Univ.</td>
</tr>
<tr>
<td>Thomson scattering</td>
<td>Design of the LIDAR system</td>
<td>Feasibility check on the high-power laser for LIDAR</td>
<td></td>
<td></td>
<td>Osaka Univ. Inst. for Molecular Science</td>
</tr>
</tbody>
</table>

Red: Reactor Design  
Green: R&D

(1-2) Organization of FERP

- FERP consists of 13 task groups and 44 subtask groups
- Leaders meeting (Exec. Dir. + 2 Div. Dir. + 13 TG leaders)
- Project meeting (Researchers from NIFS and ex-NIFS)
(1-2) Organization of FERP

- FERP consists of 13 task groups and 44 subtask groups
- Leaders meeting (Exec. Dir. + 2 Div. Dir. + 13 TG leaders)
- Project meeting (Researchers from NIFS and ex-NIFS)

Young Researchers are nominated as the TG leaders!
Any Researcher Can Participate in FERP Across the Department of Helical Plasma Research

New Organization (FY2010 ~)

From the FY2010, 4 projects have started in the new organization for the 2nd Mid-term goal & plan:

Fusion Engineering Research Project
With about 60 staffs, mainly based on the 2 divisions:

- Device Engineering and Advanced Physics Research Division (Staffs: 7,7,4)
  - LHD maintenance and D-D safety devices
  - Trace tritium monitoring and handling

- Fusion System Research Division (Staffs: 6,5,8)
  - Helical reactor DEMO design
  - Remote maintenance and replacement
  - Low activation mater. and long-life liq. blanket
  - PWI and high-heat flux components
  - Atomic and molecular processes

Relations to Other Groups
Network for promotion of engineering research

Large-scale high-field SC magnet research

- Institute for Materials Research: HFLSM, Tohoku University
- Research Institute of Superconductor Science and Systems, Kyushu University
- Tokyo Institute of Technology, Osaka Univ., Tohoku Univ., Toyohashi Univ. of tech., Tokai Univ., Kagoshima Univ., Japan Atomic Energy Agency, etc.

Trace tritium control technology research

- Hydrogen Isotope research Center, University of Toyama,
- Radiochemistry Research Laboratory, Shizuoka University

Long lifetime liquid blanket research

- Institute of Engineering Innovation, School of Engineering,
- University of Tokyo
- Institute of Advanced Energy, Kyoto University
- Tokai Univ., Tokyo Institute of Technology, Osaka Univ., Saitama Univ., Univ. of Toyama, Univ. of Fukui, Kyushu Univ., Japan Atomic Energy Agency, etc.

High heat flux plasma-facing wall research

- Plasma Research Center, University of Tsukuba
- Graduate School of Engineering, Osaka University

Low-activation structural materials research

- Institute for Materials Research, Tohoku University
- Institute of Advanced Energy, Kyoto University
- Hokkaido Univ., Muroran Institute of Technology, Hokkaido Institute of Technology, Tohoku Univ., Shizuoka Univ., Univ. of Fukui, Osaka Univ., Kyushu Univ., Japan Atomic Energy Agency, etc.
(1-3) Research Environment

<table>
<thead>
<tr>
<th>Year</th>
<th>The main fusion engineering research equipment in NIFS</th>
<th>Events</th>
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<td>2030</td>
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Devices for engineering research in NIFS since 1989
Large Supplementary Budget of 2.4 Billion JPY in FY2012

(1) SC Magnet
- 13 T SC magnet test facility, ...

(2) Blanket
- Twin loop with 3T SC magnet, ...

(3) Low-Activation Material
- HIP device, TEM, creep test device, ...

(4) Divertor
- High heat load test device of 10 MW/m², pelletron tandem accelerator of 1 MV, ...

(5) Tritium
- Gas / liquid analyzer, ...
The superconductor testing facility at "Superconducting Magnet Systems Research Laboratory" will be upgraded (after 25 years of operation) to increase the bias magnetic field from 9 T to 15 T so that 100 kA-class conductor samples will be tested at temperature 4 – 50 K.

**World's Highest B in a 700 mm Bore**

- Magnetic field: 15 T
- Bore diameter: 700 mm
- Current leads: Temperature-variable

**Twin Loops with 3T SC Magnet**

- Operational Recovery Of Separated Hydrogen and Heat Inquiry
- Forced circulation loops of FLiNaK (~500 °C) and LiPb (~300 °C)
- Integrated test stand with a SC magnet of 3 T

**Specifications of Orosh^2i-2**

- Pipe diameter: 1 inch
- Normal operation temp.: FLiNaK 500 °C, LiPb 300 °C
- Maximum flow velocity: ~1.5 m/s
- Inventory: ~100 L
- Magnetic field: max. ~3 T (CS magnet), 50 cm Øx15 cm

- Simulation of temperature and flow velocity in fusion blanket
- Integrated tests of MHD pressure drop, control of laminar and turbulence flow, hydrogen and heat recovery, corrosion behavior etc. under intense magnet field.
- Test stand for elemental technologies developed in collaborative studies.
**HIP Device, TEM, Creep Test**

R&D on low-activation materials by Blanket TG

- Characterization of nano-particle dispersion
- Evaluation of high temperature strength and low temperature ductility

**Target (non-irradiation)**
- Yield stress: 300 MPa
- Thermal creep: <1% at 100 khr
- DBTT: < RT

- Establishing fabrication technology

**High Heat Load Test Device**

R&D by In-Vessel Components TG

- **ACT-2**
  - Ultra high heat flux test stand
  - 10 MW/m² of heat loading by 300 kW electron gun
  - Large vacuum vessel
  - R&D on material, cooling media, and bonding technique
  - Realistic scale components

300 kW electron gun

*Schematic of ACT-2*
Accelerator for Material Test

R&D by In-Vessel Components and Blanket TGs

✓ Non-destructive analysis
  - By 1 MV pelletron tandem accelerator
  - Quantification of the retained H
  - Multiple analysis of RBS, ERD, NRA, and PIXE

1 MV tandem accelerator

Advanced fuel cycle system

R&D by Tritium TG

✓ Proposal of a simplified fuel cycle system
  - toward low tritium inventory

Feasibility studies of a low temperature processing
- Fuel purification processing by three stage cryogenic condensation system (Supported by Dr. Iwamoto (NIFS))
- Hydrogen isotope separation by cryogenic pressure swing absorption system (Kyushu Univ., Dr. Koike)

Proposal of tritiated water processing
- Tritiated water processing by dual temperature and dual pressure type CECE system (Nagoya Univ., Dr. Sugiyama)
- Highly tritiated water processing by gas phase processing system (Univ. of Toyama, Isidori Industrial Co., Ltd.)

Support by gas and liquid analyzers
- Advanced gas phase tritium analyzer (Proportional counter with a pulse shape discriminator) (Nagoya Univ., Kyoto Univ.)
- Advanced tritiated water analyzer (Solid scintillator type) (OHYO KOKEN KOYO CO., LTD)
- Stable Isotope analyzer (FTIR spectrometer, Gas / liquid / solid surface)
- Gas chromatograph/mass spectrometer (Analyzer in operation)
<table>
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<tr>
<th>Points of Evaluation</th>
<th>Facts</th>
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| 1-1 Whether or not the target of FERP, initiated in FY2010, is appropriate          | The target of FERP ("Promotion of conceptual and baseline designs toward realization of a steady-state helical fusion reactor and construction of engineering basis that enables real-scale and real-environment R&D") is appropriate:  
  ✓ FERP has successfully launched as the project of NIFS  
  ✓ Roadmap and tasks to do are defined with five fundamental R&Ds |
| 1-2 Whether or not the organization of FERP is coincident with its target and properly functioning? | The organization of FERP coincide with the target and properly functioning:  
  ✓ 13 TGs are organized based on the tasks defined by the target  
  ✓ The leaders meeting is properly leading the project  
  ✓ The project meeting of more than 70 times has been held  
  ✓ Collaborations with other groups are being carried out successfully |
| 1-3 Whether or not an appropriate research environment is provided for the establishment of academic fundamentals | The research environment in NIFS is being provided appropriately:  
  ✓ Five fundamental R&Ds are going on successfully  
  ✓ Collaborations with other groups are being carried out successfully  
  ✓ The research environment is now widely improving with the large supplementary budget in FY2012 |


~ Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor

(2-1) Helical fusion reactor design

(2-2) R&D toward establishment of the engineering basis
**Helical Fusion Reactor Design**

- Conceptual design of FFHR-d1
- The newest version of FFHR series
- Phased design activity
- Each consideration stage is called the 'Round'

**Round 1 (FY 2010 – 2011)**

- Determination of basic device parameters of FFHR-d1
- Design of in-vessel components
- Collaboration with LHD / Numerical Simulation Research projects

**Round 2 (FY 2011 – )**

- Design of in-vessel components
- Collaboration with LHD / Numerical Simulation Research projects

---

**1st Round**

1. Estimate radial profiles in FFHR-d1 by extrapolating the profile data obtained in LHD (DPE: Direct Profile Extrapolation)
2. Identify the design window by an integration code HELIOSCOPE
3. Determine the radial build by taking into account the shrinkage of cooled devices
4. TBR estimation by neutronics calculation of the breed and shield blankets
5. Cooling simulation of SC helical coils to determine the tolerable nuclear heating
2nd Round
Design of in-vessel components

- Blanket TG
  - 3D blanket design
  - 3D neutronics
- Design Integration TG
  - Consistency check
  - Numerical model
- In-vessel components TG
  - Divertor design
  - Pumping

Estimation of the neutron flux distribution by the 3D simulation code MCNP [Blanket TG]

Design of the pumping ducts to realize a high-conductance [In-vessel components TG]

Numerical modeling of the blanket poloidal shape being consistent with plasma and divertor legs at arbitrary toroidal angle [Design integration TG]
Structural Analysis with 3D-CAD

Large maintenance ports are applicable with tolerable EM stress

- Numerical modeling of in-vessel components
  - Make modification of the design and translation between CAD softs easy

- 3D structural analysis
  - Von Mises stress < 660 MPa with 250 mm thick helical coil case

- Maintenance scenario
  - Parallel maintenance from large 10 ports

Results of structural analysis

3D Neutronics Analysis

Neutron flux can be reduced at divertor set behind the blanket

- Sufficient radiation shielding and tritium breeding (TBR: ~1.08) performances of the FLiBe blanket have been shown by MCNP
- Irradiation damages on divertors set behind the radiation shield will be ~1/10 (1.0-1.6 dpa/y) at inboard and ~1/100 (0.06 dpa/y) at outboard compared with those at the first wall
- Possibility of applying copper alloy for divertor cooling emerges
Inter-Project Collaboration
With the LHD project and the Numerical Simulation Research Project

1 Proposal of experiments in LHD using the similar magnetic configurations as FFHR-d1

The number of poloidal coils is reduced from 6 in LHD to 4 in FFHR-d1 to secure large maintenance ports.

2 Plasma experiment and estimation of the radial profiles in FFHR-d1 by DPE (Direct Profile Extrapolation)

Shafranov shift is mitigated in the high aspect ratio configuration (red and magenta) compared with the standard configuration (blue).

3 Identification of the MHD equilibrium in FFHR-d1 using HINT2 and VMEC

Magnetic surfaces are destructed at high-beta (left) can be restoration by the plasma position control (right) [HINT2]

4 Detailed physics analysis

Both of the alpha re-entering effect and the plasma position control is effective to reduce the alpha loss [MORH]

Operation Scenario is Being Established

✓ Quasi 1D plasma simulation
- Profile effect is taken into account based on NGS (Neutral Gas Shielding model) and DPE (Direct Profile Extrapolation method)

✓ Detailed physics analyses
- Shafranov shift mitigation is possible
- Neoclassical loss and alpha loss are tolerable

Results of core plasma simulation

Neoclassical thermal loss is compatible with the α heating

Magnetic surfaces similar to those in vacuum are obtained at high beta by applying Bv

Direct loss of alpha particles is tolerable

Ratio of confined alpha

Confined

Lost
Five fundamental engineering studies are ongoing

**SC Magnet**
- R&D on three kinds of SC Magnet
  - Demonstration of 100 kA in HTS coil

**Tritium / Safety**
- R&D on hydrogen isotope processing

**Blanket**
- R&D on elemental technologies for liquid blanket
  - Demonstration of FLiNaK circulation in Orosi-H-1

**High Heat / Particle Load Handling**
- R&D on the divertor device
  - Bonding of W and Cu / RAFM
  - Detachment exp. in LHD

**Low-Activation Materials**
- R&D on V-alloy and coating
  - Improved characteristics of V-alloy at ~700 °C
  - Double layer ceramic coating

Collaboration with LHD
- FFHR configuration
- Material test
- EBW
- Hydrogen isotope processing
- Neutron diagnostics

---

**R&D on SC Magnet**
Three types of SC conductor have been developed

**High-Temperature Superconductor**
- High-Temperature Superconductor (HTS) with GdBaCO has achieved 100 kA@20 K, 5 T and 120 kA@4.2 K, 0.4 T
- Mechanical lap-joint developed by Tohoku Univ. has satisfied required joint resistance

**Indirectly-cooled Nb3Sn conductor**
- Indirectly-cooled Nb3Sn conductor with Rutherford cable and Al-alloy jacket with Friction Stir Welding is being developed
  - 5 kA@12 T-class sample was tested as a three-turn coil
  - 20 kA@12 T-class & 100 kA@12 T-class samples were fabricated

**CIC Conductor Testing**
- Short-sample conductors and CS model coil were tested for JT-60SA
- Conductor joint test is being carried out for ITER-TF
Progress in the HTS Option of Helical Coils

- HTS: High Temperature Superconductor
  - High cryogenic stability (no worry of quench)
  - High mechanical strength with YBCO
- Segmented-fabrication (jointed-winding) of helical coils
  - Accelerate the manufacturing process
  - No need of large winding machine
- R&D on the jointed HTS coil
  - One turn HTS coil sample with a mechanical joint
  - 100 kA coil current has been achieved @ 20 K, 5 T

R&D on Blanket

Elemental technologies for liquid blanket have been developed

- Data acquisition of plasma driven hydrogen permeation through F8zH at 520 °C
- Analysis of hydrogen retention in F8zH after He plasma pre-irradiation
- Completion of construction of FLiNaK loop Orosh1-1 and start of operation.
- Development of electrically insulated hydrogen recovery unit for molten salt coolant
FLiNaK Circulation
Experiment in Oroshī-1

FLiNaK circulation loop system
“Oroshī-1”
Operational Recovery Of Separated Hydrogen and Heat Inquiry

**Specification of Oroshī-1**
- Pipe diameter: 1/2 inch
- Maximum temperature: 600 °C
- Maximum flow velocity: ~0.5 m/s
- Inventory: ~3 L

✓ The world’s first integrated molten salt loop system for study of separate recovery of hydrogen and heat

✓ Successful control of FLiNaK circulation and velocity measurement at 500 °C
  - Operation of centrifugal pump for high temperature molten salt has been demonstrated

✓ Development and experience accumulation on
  - Circulation control of high temp. molten salt
  - Velocity measurement
  - Hydrogen charge and recovery
  - Handling of molten salt etc.

R&D on Vanadium Alloys and Ceramic Coating

✓ V-alloys are promising low activation structural material
  - Microstructural control => high-T strength  
  - Mechanical-alloying and HIP => both strength and elongation  

✓ Ceramic coating is essential to breeding blankets
  - For electrical insulation, and
  - Reduction of the tritium permeation
  - Double layer Er2O3 coating technique on the tube interior has been developed
R&D and Related Researches on Divertor

- Bonding of tungsten with other metals
  - Brazing of tungsten mono-block with copper alloy tube
  - Bonding of tungsten mono-block with F82H tube by HIP
- Divertor detachment for heat load reduction
  - Detachment experiments in LHD, by
    - Impurity gas puffing
    - Edge density limit at high density
    - RMP (Resonant Magnetic Perturbation)

Various researches are also ongoing
- Evaluation of the enhanced radiation loss by Ne
- Spectroscopic study on W
- Interaction between W and hydrogen
- Plasma irradiation test of PFC materials
- Neutral particle simulation (EIRENE)
- MD simulation on C and W
- Configuration optimization for asymmetry mitigation
- Strike-point sweeping for erosion mitigation


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<th>Points of Evaluation</th>
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<td>Many research results have been achieved throughout the reactor design activity and related R&amp;Ds in FERP: 19 presentations in total have been given in the international conferences (invited: 14, oral: 26) 217 papers in total have been published</td>
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<tr>
<td>2-1 Helical fusion reactor design</td>
<td>Conceptual design of the helical reactor FFHR-ds is proceeding: 37 presentations related to the FFHR-ds design have been given in the international conferences (invited: 4, oral: 3) 81 papers related to the FFHR-ds design have been published</td>
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<td>2-2 R&amp;D toward establishment of the engineering basis</td>
<td>R&amp;Ds on SC magnet, blanket, low-activation materials, divertor, and tritium have been conducted: In collaboration with universities 113 presentations on these R&amp;Ds have been given in the international conferences (invited: 10, oral: 23) 236 papers on these R&amp;Ds have been published</td>
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### [3] Encouragement of Joint Activities and Collaborative Research

#### (3-1) Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others

大学等が有する高い研究能力を結集して、COEとして共同研究を適切に進めているか

#### (3-2) Whether or not NIFS is contributing to the development of research at universities

大学の研究発展に寄与しているか

#### (3-3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others?

ITER計画やBAなど国際的な活動との連携、貢献を図っているか

### (3-1) Collaboration

Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others

大学等が有する高い研究能力を結集して、COEとして共同研究を適切に進めているか

**Collaborations on Fusion Engineering in 2010-2013: 542 in Total**

- ✓ 266 under NIFS collaborations
  - 52 on reactor design
  - 69 on SC magnet system
  - 101 on in-vessel components
  - 25 on isotope / environment
  - 19 on numerical simulation / analysis
- ✓ 64 under LHD project collaborations
- ✓ 91 under bilateral collaborations
- ✓ 40 with private companies
- ✓ 81 by external funds (71 by grant-in-aid of MEXT)
Statistics of Collaboration

General joint research collaborations

LHD project research collaborations

Bilateral research collaborations

Research collaborations with private companies

---

(3-2) Research at Universities

Whether or not NIFS is contributing to the development of research at universities

- Tokai University
  - Plasma operation scenario
  - HTS (YBCO) current lead
- The University of Tokyo
  - System code
  - Application of HTS in Mini-RT
  - Material study for liquid blankets
- Tohoku University
  - HTS (YBCO) mechanical joint
  - MHD pressure loss mitigation
  - Fatigue life evaluation
  - Heat removal in FLiBe blanket
- W alloy
- Kyushu University
  - Tritium balance
  - Hydrogen isotope separation
  - Neutron irradiation effect on SC magnet
  - Environmental dynamics of OBT
- Kagoshima University
  - Stability of HTS (MgB2) conductor
- Sophia University
  - Current Inhomogeneity in CIC conductor
- Toyohashi University of Technology
  - Detection of partial discharge in SC magnet
- Hokkaido University
  - Plasma irradiation effect on H/He retention

- Nagano National College of Technology
  - Hydrogen isotope oxidation
- Kyoto University
  - W coating on low activation materials
  - Energy conversion in divertor
- Akita University
  - Hydrogen isotope trapping
- Shizuoka University
  - Dynamics of hydrogen transport
- Osaka University
  - PWI study using laser / ion beam induced plume
- Kanazawa University
  - Graphite divertor life
- The University of Electro-Communications
  - Spectroscopic study of W by EBIT
- Niigata University
  - Charge exchange between W and H
- Nagoya University
  - Neutron measurement system
  - Li isotopes separation
- University of Occupational and Environmental Health
  - Biological effect of T
- Akita University
  - Hydrogen isotope trapping

... and so on
Example of Cooperative Activities in the NIFS Fusion Engineering Research Project

- e.g., Recovery efficiency of hydrogen isotope
  - Important to elucidate the tritium transport in fusion reactor
- Lab. scale experiment of hydrogen circulation in Shizuoka Univ.
  - Named “EXPRESS”
  - Consists of plasma formation system, gas purification system, and gas stock

Collaboration Network

Carried out in coordination with the research promoted by Universities
(3-3) International Activities

Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others?

○ ITER
  - SC magnet: ITER-TF coil, cryo system
  - NBI: beam simulation, experiments

○ BA
  - JT-60SA: SC magnet
  - IFERC DEMO R&D: RAFM, SiC, PWI exp. in JET
  - IFERC DEMO Design: cost model
  - IFMIF-EVEDA: fatigue life evaluation

○ TITAN
  - Permeability test of Er₂O₃ coated RAFM in Idaho National Laboratory (INL)
  - MHD pressure loss experiment in UCLA (with Tohoku university)
  - Irradiation effect on jointing materials (with Osaka university)

○ GENIE
  - Provision of atomic and molecular database

Collaboration with ITER

○ SC magnet and cryo system
  - ITER-TF coil testing
  - Cryo system simulation code C-PREST

○ Neutral Beam Injection (NBI)
  - Beam simulation
  - Experiments in NIFS test stand

Performance test of the ITER-TF connection part in NIFS
Simulation results of the heat transfer to LHe reservoir, by C-PREST made in NIFS
3D-beamlet simulation including secondary charged particles
Collaboration with BA

- JT-6oSA
  - SC magnet testing
- IFERC
  - Precipitation behavior of F82H-BA07 during aging and creep
  - Electrical conductivity and hydrogen permeability of SiC materials under irradiation
  - Cost model
  - PWI experiment in JET
- IFMIF-EVEDA
  - Fatigue life evaluation using small specimen

The extraction residue of RAFM (Reduced Activation Ferrite Materials) and the particle size distribution (in each bar)

The radiation-induced conductivity in various ceramic materials

Collaboration on TITAN

- Japan-US collaboration on Tritium, Irradiation and Thermofluid
  - Following JUPITER and JUPITER-II

- Recent Topics
  - Permeability test of Er₂O₃ coated F82H using tritium in Idaho National Laboratory
  - Mitigation of MHD pressure loss by partial electrical isolation (with Tohoku University)
  - Irradiation effect on jointing materials (with Osaka Univ.)

Pressure loss dependence on the flow velocity of Li-Pb in a channel with electrical isolation on three-sides
Collaboration on Atomic and Molecular Database

✓ NIFS is Providing the largest database to GENIE
  - GENIE is the worldwide search engine of atomic and molecular database
  - Organized by DCN (IAEA)

Summary of [3] Encouragement of Joint Activities and Collaborative Research

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| 3-1 Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others | 542 collaborations have been performed on the engineering issues of:
  ✓ SC magnet, cryo system, reduced activation material, blanket, divertor, tritium, reactor design, and so on |
| 3-2 Whether or not NIFS is contributing to the development of research at universities | A lot of important researches have been performed at universities, under collaboration with NIFS |
| 3-3 Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others? | FERP is contributing to ITER, BA, TITAN, atomic and molecular database, by closely cooperating with them |

- Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study

- 22 papers have been written by the students grown up through the collaboration with FERP

- A half of the students are now working in fusion-related technology fields
  - Graduated from universities collaborating with FERP
  - 420 collaborations have been carried out by FERP and universities in these 4 years

TG Leaders of FERP are YOUNG

- Most of them are the thirties or forties
  - Each of them is aware of his/her responsibility for realizing the fusion energy

Breakdown of published papers
Future Plan

- Whether or not the future plan is appropriately pointing at the medium- to long-term target

✓ Next Move on Reactor Design
- New approach
- 3rd round
- Starting peer review with JAEA

✓ Next Move on R&D
- Promotion of the 5 major R&Ds toward real-scale and real-environment test in the 3rd mid term

New Approach
Starting discussion on FFHR-d1A, d1B, d1C, and c1

✓ FFHR-d1A is the base for 3D designs with a modified aspect ratio by reducing the Shafranov shift
✓ FFHR-d1B is a flexible design for the ignition core with the magnetic (B) field enhanced by 20%
✓ FFHR-d1C is another flexible design with configuration optimization of vertical field coils
✓ FFHR-c1 is a sub-ignition version as “before-demo, compact and component-test”

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<th>FFHR-d1B</th>
<th>FFHR-d1C</th>
<th>FFHR-c1.0</th>
<th>FFHR-c1.1</th>
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<td>( A_c (\text{m}) )</td>
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<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
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<tr>
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<td>1,823</td>
<td>1,823</td>
<td>1,823</td>
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<tr>
<td>( f_D )</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
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</tr>
<tr>
<td>( \nu_{\text{eff}} (\text{GJ}) )</td>
<td>202.8</td>
<td>202.8</td>
<td>202.8</td>
<td>202.8</td>
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</tr>
<tr>
<td>( z )</td>
<td>1.23</td>
<td>1.23</td>
<td>1.23</td>
<td>1.23</td>
<td>1.23</td>
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<tr>
<td>( r_e )</td>
<td>1.0</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>( n_B )</td>
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<td>5.1</td>
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<tr>
<td>( \nu_r (\text{MF}) )</td>
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<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
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<tr>
<td>( \nu_{\text{mag}} (\text{GJ}) )</td>
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<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>( \theta )</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>( \theta_m (\text{MF}) )</td>
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<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
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</tr>
</tbody>
</table>
Starting Peer Review with JAEA
Renewal of the collaboration style with JAEA

1994: Collaboration on FFHR design started
2013: All Japan combined team for DEMO development planning launched

⇒ Reinforcement of collaboration with JAEA

[Fusion Research Development Working Group]

[Schedule]
25-27 Nov. 2013: 1st Meeting @ Rokkasho
Feb./Mar. 2014: 2nd @Toki
May/Jun. 2014: 3rd @Rokkasho
2014: 4th @Toki

Problem-solving by peer review
- Helical reactor design by NIFS (FERP)
- Tokamak reactor design by JAEA

<table>
<thead>
<tr>
<th>Points of Evaluation</th>
<th>Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4</strong></td>
<td>Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study</td>
</tr>
</tbody>
</table>
| | FERP is bringing up young researchers:  
| | ✓ 22 papers have been written by students who collaborated with FERP  
| | ✓ A half of the students found their jobs in the fusion-related technology fields  
| | ✓ Most of the TG leaders of FERP are 30ies or 40ies who are actively playing important roles in the international fusion community |
| **5** | Whether or not the future plan is appropriately pointing at the medium-to-long-term target |
| | The future plan of FERP is appropriate:  
| | ✓ Reactor design will proceed to the next step, to draw a concrete view of the helical fusion reactor  
| | ✓ R&Ds and collaborations with universities will be accelerated by operating the devices provided by the large supplementary budget in FY2012 |
Points of Evaluation based on Proposals from the External Evaluation in FY2009

1. Whether or not fusion engineering research is developed across the board with the emphasis on helical reactors design

2. Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership from the international research point of view

3. Whether or not NIFS continues to develop superconducting coils for fusion reactor development

4. Whether or not efforts are being made to encourage young researchers to participate in the fusion reactor research project

5. Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors

Tasks have been Taken Over

Researches before 2010 are continued with additional tasks in FERP since 2010

<table>
<thead>
<tr>
<th>Subject</th>
<th>Task</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHD</td>
<td></td>
<td></td>
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<tr>
<td>B&amp;D for Reactor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutronics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnet System</td>
<td></td>
<td></td>
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<tr>
<td>Reactor DR</td>
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<td></td>
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<tr>
<td>Ignition system</td>
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<tr>
<td>Neutronics</td>
<td></td>
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<tr>
<td>SC magnet</td>
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</tr>
<tr>
<td>Tritium Monitor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tritium Recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare for Deuterium Experiments in LHD</td>
<td></td>
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</table>
Points of Evaluation based on Proposals from the External Evaluation in FY2009

<table>
<thead>
<tr>
<th></th>
<th>FY2009</th>
<th>FY2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Whether or not fusion engineering research is developed across the board with the emphasis on helical reactors design</td>
<td>FERP is developing the fusion engineering research:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ With the researchers from various scientific fields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Collaboration with LHD project / Num. Sim. Res. Project on FFHR-d1 is successfully ongoing</td>
</tr>
<tr>
<td>2</td>
<td>Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership from the international research point of view</td>
<td>FERP is internationally leading the study on advanced blanket and reduced activation materials:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Especially on the FLiBe blanket and V alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Twin loops for molten salt / LiPb circulation test with 3T magnetic field will be the &quot;only one&quot; in the world</td>
</tr>
<tr>
<td>3</td>
<td>Whether or not NIFS continues to develop superconducting coils for fusion reactor development</td>
<td>FERP is continuing to develop three types of SC magnet for fusion reactor:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Collaboration with ITER and BA (JT-GoSA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Jointed winding of HTS helical coil is the new original idea</td>
</tr>
<tr>
<td>4</td>
<td>Whether or not efforts are being made to encourage young researchers to participate in the fusion reactor research project</td>
<td>FERP is encouraging young researchers to join:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Young researchers are nominated as TG leaders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Important issues are assigned to young researchers</td>
</tr>
<tr>
<td>5</td>
<td>Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors</td>
<td>YES, we think so! HOW about you?</td>
</tr>
</tbody>
</table>

Summary of Publications and Collaborations on Fusion Engineering

1. Publications in 2010-2013: 217 in total
   - 136 on R&D
     - 17 on SC magnet & Cryogenics, 25 on Low activation materials, 61 on Blanket & First wall, 46 on Divertor, 36 on Tritium & Safety
     - 82 on Reactor Design
       - 28 on Concept & System design, 21 on Core plasma control, 11 on Plant equipment & related technology
     - 82 written by non-NIFS staffs
     - 22 written by students

2. Collaborations in 2010-2013: 542 in Total
   - 266 under NIFS collaborations
     - 32 on reactor design, 69 on SC magnet system, 101 on in-vessel components, 25 on isotope / environment, 19 on numerical simulation / analysis
     - 64 under LHD project collaborations
     - 91 under bilateral collaborations
     - 40 with private companies
     - 81 by external funds (72 by grant-in-aid of MEXT)
“Interim Report on the Conceptual Design of the FFHR-d1 Helical Fusion Reactor” has Come Out

- Reduced version was published in Journal of Plasma and Fusion Research

(2-2) Whether or not the organization of FERP is coincident with its target and properly functioning?
Budget for Fusion Engineering Research Project

- NIFS facility budget is 4.8 Billion JPY in FY2013.
- Annual budget for NIFS collaboration related to fusion engineering is about 100 Million JPY, which is mainly used in universities.

Supplementary budget of 2.4 Billion JPY for facility

### Requested for FERP

<table>
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<tr>
<th>Year</th>
<th>Special Budget</th>
<th>Annual Budget</th>
<th>Total</th>
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<td>FY2011</td>
<td>0.87 B</td>
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<td>FY2012</td>
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<tr>
<td>FY2013</td>
<td>0.63 B</td>
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<td>FY2014</td>
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<td>FY2015</td>
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<td>Total</td>
<td>4.00 B</td>
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</table>

**Establishment of fusion engineering area by 5 large-scale experimental researches**

1. **Reduced activation materials**
   - Y 0.88 B JPY
   - Proposal of safe and long-life materials

2. **Large-scale, high-field superconducting magnet**
   - Y 1.20 B JPY
   - Proposal of stable and long-life superconducting magnet

3. **High heat flux plasma facing components**
   - Y 0.93 B JPY
   - Proposal of stable and long-life plasma facing wall

4. **Long-life liquid breeder blanket**
   - Y 0.85 B JPY
   - Proposal of safe and long-life power generation system

5. **Trace tritium handling technology**
   - Y 0.20 B JPY
   - Establishment of highly-accurate, highly-efficient and safe tritium processing system

**Future fusion reactor**
- Stable, safe and secure basic energy source
- World standard of Japanese origin
- Human resource development
- Environmental preservation

**1GW electricity production**
- Stable, safe and secure basic energy source
- World standard of Japanese origin
- Human resource development
- Environmental preservation

**Supplement**
- FERP requested the total 4 Billion JPY in 6 years for facility and operation
# Research Achievements

- Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor

<table>
<thead>
<tr>
<th>Year</th>
<th>International Conference</th>
<th>Presentations by FERP and collaborations</th>
<th>Presentations Total</th>
<th>Ratio</th>
<th>Reference</th>
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<tbody>
<tr>
<td>2010</td>
<td>26th Symposium on Fusion Technology (SOFT 2010)</td>
<td>12</td>
<td>547</td>
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<td>FED Vol.86 Issues 6-8, 9-11</td>
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<tr>
<td>2010</td>
<td>9th International Conference on Tritium Science and Technology (TRITIUM2010)</td>
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<td>19th ANS Topical Meeting on the Technology of Fusion Energy (TOFE 2010)</td>
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<td>2011</td>
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<td>FED Vol.87 Issues 5-6, 7-8</td>
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<tr>
<td>2011</td>
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<td>INM Vol.442 Supplement 1 / FST Vol.61 No.1</td>
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<tr>
<td>2012</td>
<td>20th International Conference on Plasma Surface Interactions in Fusion Devices (PSI-20)</td>
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<td>INM Vol.438 Supplement</td>
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<td>2012</td>
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<td>2013</td>
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<td>525</td>
<td>3.0%</td>
<td>ISFNT-11 Book of Abstract</td>
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## Results of FERP Evaluation 2013

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<td>10</td>
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<td>5</td>
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<td>4.29</td>
<td>4.35</td>
<td>4.50</td>
<td>4.06</td>
<td>4.47</td>
<td>4.31</td>
<td>3.94</td>
<td>3.82</td>
<td>3.88</td>
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### Evaluation Scoring

<table>
<thead>
<tr>
<th></th>
<th>Extremely highly commendable</th>
<th>Highly commendable</th>
<th>Commendable</th>
<th>Adequate</th>
<th>Inadequate</th>
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</thead>
<tbody>
<tr>
<td>S</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
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<td>A</td>
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</tbody>
</table>

※ This table contains all the scores given by both Japanese and foreign reviewers. Total numbers vary by item because some were left blank.

### Items

#### [1] Establishment of research system and environment

- [1](1) Whether or not the target of FERP, initiated in JFY2010, is appropriate
- [1](2) Whether or not the organization of FERP is coincident with its target and properly functioning
- [1](3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

#### [2] Research achievements

- [2](1) Helical fusion reactor design
- [2](2) R&D toward establishment of the engineering basis

#### [3] Encouragement of joint activities and collaborative research

- [3](1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes
- [3](2) Whether or not NIFS is contributing to the development of research at universities
- [3](3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

#### [4] Human resources development

- [4] Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

#### [5] Future plans

- [5] Whether or not the future plan is pointing appropriately toward the medium- to long-term targets
### Item-by-item average scores

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<tbody>
<tr>
<td><strong>Average scores</strong></td>
<td>4.35</td>
<td>4.29</td>
<td>4.35</td>
<td>4.50</td>
<td>4.47</td>
<td>4.31</td>
<td>3.94</td>
<td>3.82</td>
<td>3.88</td>
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