

National Institute for Fusion Science (NIFS)

National Institutes of Natural Sciences (NINS)

Peer Review Reports in FY2007



March, 2008

NIFS Administrative Council External Peer Review Committee

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Chapter 1 Peer Review Report on Large Helical Device (LHD) Research

1.1 Summaries and Recommendations

1.1.1 Summaries of the Review

Following is the Summary of opinions of the External Peer Review Committee members about reviews made from the eight indispensable perspectives based on reviews for the achievement as well as research standard of the Large Helical Device (LHD) project, of which the National Institute for Fusion Science is charged in the Mid-Term Plan defined by the National Institutes of National Sciences, the Inter-University Research Institute. [1] to [4] are the terms printed in the Mid-Term Plan, and [5] and [6] are the related terms.

[1] By achieving things written below, did we succeed in an academic systematization and also produce outstanding results that led the world in the field of nuclear fusion science as well as in the fields like plasma physics and fusion engineering that are the basis of nuclear fusion science to actualize the fusion energy?

(1) Did we succeed in enhancing the plasma performance to see through the nuclear fusion core plasmas?

In LHD, specific goals for the plasma performance were defined upon its construction to solve five critical research issues. Toward these goals, necessary equipment has been provided: buildup of NBI, development of the pellet injection device, and so on. As a result, generation of ultra-high density plasmas ($1.1 \times 10^{21} \text{m}^{-3}$), high β value (5%), long-pulse plasma sustention (54min), and high central ion temperature (6.8 keV) as well as high central electron temperature (10keV) have been achieved. These results can be rated high from the aspect to improve the plasma performance to see through the nuclear fusion core plasmas.

The performance is being steadily improved such as the increase in nuclear fusion triple products and in electron and ion temperatures. Their progress is said to be a big advance from the aspect that proposes a new approach toward the realization of helical-type nuclear fusion reactor. Further advance in performance can be expected when the deuterium experiment starts.

On the other hand, the heating power is considered insufficient in the long-pulse demonstration experiment. A reasonable reinforcement plan for heating devices is necessary.

(2) Did we properly carry out the academic scientific research for the comprehensive understanding of torus plasmas and the actualization of nuclear fusion core plasmas?

The actualization of nuclear fusion core plasmas requires enough confinement of high-temperature high-density plasmas. Furthermore, magnetohydrodynamically stable high-beta plasmas are necessary to design an economic fusion reactor. From these perspectives, the fact that varieties of academic research toward the comprehensive understanding of torus plasmas—namely the high-density high-beta plasma confinement research, the research in pressure-drive magnetohydrodynamic instability, the research in ITB (internal transport barrier) and the zonal flow to improve confinement, and so on—are carried out in the LHD research by using the accurate diagnosis of plasma parameters while in consideration of the comparison with tokamak can be highly valued.

In the meantime, it will be much expected that the research in recycling control by a closed diverter would make further contribution to the comprehensive understanding of a torus plasma confinement. Also, clarification of the mechanism of impurity hole found in LHD and intensification of activities of theory and data analysis for the edge plasma behavior will be anticipated as well.

[2] To carry out the perspective [1], did we perform the following?

(1) Did we properly carry out the maintenance and intensification of heating devices as well as diagnostic devices and the improvement of devices?

Intensive investments for the development of the low-energy perpendicular NBI for the purpose of an increase in the direct heating power to ions, particle supply to the plasma core, and high-accuracy ion temperature distribution diagnostics brought forth the achievement of high central ion temperature and the discovery of impurity hole. The development of a continuous serial pellet injection device enabled a long-pulse sustention experiment for the high-density high-confinement discharge. Also, in addition to the performance upgrading and routine diagnosis of fundamental diagnostic devices like the Thomson scattering device and the carbonic acid gas laser interferometer, the development of a high-accuracy charge exchange recombination spectroscopy, an imaging interferometer that utilizes carbonic acid gas lasers, and a tracer-encapsulated pellet injection method enhanced a plasma diagnostic technology to contribute to the elucidation of a plasma behavior. The upgrade of heating devices and diagnostics as well as their improvement are the results of a proper research plan and the consequences of research and development that executed the plan accordingly. Thus, their effort can be highly valued.

Besides, the reinforcement and equipment of heating machines in preparation for the expected deuterium experiment are appropriate. For these, too, a high opinion shall be given. Now, the intensification of heating devices necessary to improve the plasma performance and the development of diagnostic devices to promote academic research will be expected continuously.

(2) Did we properly carry out the research to elucidate the physical organization necessary to improve the plasma performance as a bilateral collaborative research by organically utilizing devices and equipments of various research institutes, universities, university research institutes, and research centers?

Quite active and diverse collaborative research is carried out by utilizing the bilateral collaborative research system, bringing many significant results. Results of these collaborative researches facilitated the comprehensive understanding of torus plasmas, one of the LHD research goals; thus, it can be highly valued. To name a few, a collaborative research regarding the confinement improvement and helical magnetic field configuration is carried out in Kyoto University (Heliotron J); a collaborative research for the high-temperature plasma stabilization and PWI (plasma wall interaction) as well as a collaborative plan regarding the spherical torus is carried out in Kyushu University (TRIAM-1M/QUEST); and a collaborative research to elucidate a physical organization for the plasma confinement improvement is carried out in Tsukuba University (GAMMA10). By effectively utilizing various devices and facilities in research institutes and universities, associated research institutions, and research centers in these collaborative researches, further acceleration of elucidation of physical mechanism necessary for improving plasma performance will be much anticipated.

[3] Did we properly carry out the inter-operation and collaborative research by obtaining more active participation from various research fields including the participation of those researchers who study subjects other than nuclear fusion? Accordingly, did we successfully prepare the environment? Also, did we successfully contribute to the research development of universities?

The bilateral collaborative research was newly added to the general collaborative research and the LHD collaborative research. The system to support various types of collaborative researches has properly facilitated, and the joint operations of the device and the collaborative researches have been managed well. These environmental considerations are something that the field of fusion science has worked on in advance to the other research fields. It can be highly valued as a result of sincere efforts, where NIFS and other nuclear fusion research communities have cooperated together. Numbers of research topics, researchers, and research exchange activities have been steadily increasing, and the researches are continuing to progress. Operation rules for collaborative researches were also modified, greatly contributing to the establishment of entities of research in universities as well as to the human resources training. On the other hand, university research labs can hardly keep fundamental research activities without these systems; considering these, the NIFS effort can be highly valued from

the aspect of their contribution to the plasma education in universities and the research development.

As for the collaboration with areas other than nuclear fusion, research collaborations are being carried out with areas of disciplines such as astronomy and imaging science. Also, the effort to establish an international collaborative research core network project should also be valued highly. These efforts need to be continued. High evaluation shall be given also to environmental considerations such as the establishment of the User's Office and the maintenance of nuclear fusion science archives.

[4] Did we successfully play a role as COE? Moreover, did we also play a role as COE in a global sense through international collaborative research and contributions?

NIFS fully carries out its responsibility as COE with its high research quality and as a central organization of the international collaborative research. Especially, the LHD project is selected as one of the key fusion activities in Japan, and it successfully plays a role as an international COE in the toroidal plasma research. Also, NIFS developed a collaborative system concerning Japan-US, Japan-EU, Japan-China, and Japan-Korea collaboration, taking the leadership in the international nuclear fusion research as a contact office for many international collaborative researches and international coordination. Considering these, NIFS efforts can be highly valued.

[5] Did we successfully function as an origin for the academic scientific transmission that can also transmit to the research fields other than nuclear fusion?

Applications of the results of LHD research such as the large-scale superconducting coil system, a microwave heating device, or the negative ion source technology development as well as an academic utilization of high-temperature plasmas generated in LHD were widely extended to other fields. This can be highly valued. Also, NIFS effort to act as the center for an academic transmission of knowledge should be given a high review. In the area of theory and simulation as well, the development to other fields have been lately enhanced, producing quite interesting results.

Furthermore, the inter-institutional research collaboration within National Institute of Natural Sciences is being carried out. Research results are properly released via the mass media. NIFS is considered a centripetal figure as the network origin, having strong impacts on various scientific fields. Besides, it should be noted that the public relations activities to other research fields as well as the publics are carried out with greater considerations.

[6] Did we successfully contribute to fostering of human resources who would play an active part in an international surroundings?

NIFS graduate education is carried out under 3 objectives: 1) as one of the fundamental research organizations in the School of Physical Sciences, Graduate University for Advanced Studies (Department of Fusion Science); 2) associated graduate universities with the Graduate School of Engineering and the Graduate School of Science in Nagoya University, the Graduate School of Engineering in Hokkaido University, and the Graduate School of Science and Engineering in Toyama University; and 3) educational consignment of students in other universities as a special inter-university researcher. The LHD experiments, beside these 3 human resources training, contributed to the education and research of many students in universities nationwide by developing the general collaborative research, LHD collaborative research, and bilateral collaborative research.

The Department of Fusion Science in Graduate University for Advanced Studies has produced more Ph.D. holders than quota in the past four years; and approximately 60% of these obtained their degree with subjects related to the LHD research. Lots of international students also study in the Department. Thus, the LHD experiments are producing significant educational effects and global contribution.

In the international collaboration like Japan-US, Japan-EU, Japan-China, and Japan-Korea collaboration, NIFS actively promotes a dispatch of graduate students and young researchers to foreign nations or an invitation of foreign young researchers. Their effort to train domestic as well as international researchers so that they could actively participate in an international scene can be highly valued.

Furthermore, NIFS hires several COE research assistants as postdoctoral staff. NIFS effort to foster young researchers is also worth a high review.

However, further efforts will be necessary for the training of human resources who could truly participate in the international scene including ITER. Thus, NIFS will need to come up with a unique and aggressive training program for human resources and work on the program strategically.

[7] Is our future research plan proper? Especially, is the perspective of the mid-/long-term plan that was drafted toward the actualization of a desired target value properly taken into consideration?

Goals defined in the 1st Mid-Term Plan will be most likely achieved; thus, their plan can be highly valued. Likewise, the 2nd Mid-Term Plan is well thought-out and appropriate. The deuterium experiment, installing closed diverter, and reinforce of plasma heating power for it are proposed, and the research plan is facing up to the mid to long-term perspectives. Therefore, it also can be valued highly. In the deuterium experiment, remarkable improvement in the confinement property is expected; thus, one could see the perspectives to the helical-type nuclear fusion reactor. The facts that the prospect toward a demonstration reactor

has been brightened and that a definite plan is gradually being provided shall be highly valued. Upon the start of a deuterium experiment, further development in research concerning the plasma wall interaction (PWI) will be necessary.

[8] Besides the above described perspectives, did we properly resolve the issues pointed out in the 2004 Peer Review?

(1) Were the selection of research themes and the research procedures proper? Especially for the experiments, were the opinions of the NIFS staff and collaborative researchers heard to improve the system? Also, Did we select such research themes that clearly define the contribution to ITER?

Research themes are properly determined upon discussion with the non-NIFS collaborative researchers and nuclear fusion communities in the LHD experiment meeting. While releasing the research procedure and programs on the web, theme frameworks are changed upon requests from collaborative researchers. The selection of research themes is carried out effectively. One can see some improvements toward a better system, and their effort can be highly valued. Also, contribution to ITER is made by selecting such themes that take both into consideration the commonality and complementarity with the tokamak. This can be highly valued.

(2) As for the theory and data analysis, did we successfully improve the collective strength by intensifying the collaboration with theory and simulation groups? Furthermore, did we successfully work as the center for the torus plasma theory research in Japan by intensifying the collaboration with the tokamak?

As for the theory and data analysis, NIFS has strived to build connections between theory and simulation by establishing the Department of Simulation Science. While enhancing the general ability, it has also contributed to the comprehensive understanding of the toroidal plasma and the improvement of LHD performance; thus, it can be valued highly. Furthermore, by strengthening connections with tokamak researchers, the institute has become the center for the toroidal plasma theory in Japan; their effort will deserve high marks. Not only in the area of nuclear fusion, but research that provides a spin-off to areas other than nuclear fusion is also carried out. Further contribution to LHD and development as the center for theoretical research in Japan will be much expected in the future.

(3) Did we strive to develop diagnostic devices including such advanced diagnostic devices that might be applicable to ITER while collaborating with researchers in and outside of NIFS?

In addition to the development of a shortwave far-infrared laser, high-performance polarization interferometer diagnosis, Cotton-Mouton interferometer and imaging bolometer, NIFS keeps challenging within NIFS as well as with external researchers on the R&D in the primary mirror optical characteristics deterioration and its countermeasure and such, while taking into consideration the advanced diagnostic devices that might be applicable to ITER. Their activity deserves a high review. A currently planned deuterium experiment is itself quite effective to cultivate a diagnostic method that leads to the creation of developments and experiments in diagnostic devices for ITER and similar projects; thus, contribution to ITER will be further expected than it is now.

1.1.2 Recommendations

At last, please refer to the following recommendations for the future LHD research procedure:

- (1) This time, LHD research was given a review that the current LHD plasma parameter has achieved at the level that are comparable or contrasted with a large-scale tokamak device and that its research results were as they were expected or better. Taking the latest review into consideration, it is expected that in the 2nd Mid-Term Plan, they will intensify heating devices and install closed diverters to promote a deuterium experiment plan as expected and actualize further improvement of a plasma performance. Then, a steady-state experiment under the higher-density, higher-temperature condition is also desirable.
- (2) While NIFS has produced its own research results in the LHD research by organically utilizing three collaborative research categories (general, LHD, and bilateral collaborative research), it largely contributes to the development and activation of research education activities in universities nationwide. Toward a further development in the future collaborative research activities including the staff training, further challenges will be much expected.
- (3) NIFS has already been establishing its status as global COE in the area of nuclear fusion. From now on, it will be much expected that NIFS, while realizing its role as COE, shall promote future LHD research with courage and will that dares to challenge new research. Thus, their effort will bloom the entity of LHD research that can pride itself to the world. Further development is much desired.

Chapter 2 Peer Review Report on Simulation Research

2.1 Summaries and Recommendations

2.1.1 Summaries of the Review

Following is the Summary of views of the External Peer Review Committee members.

- [1] By carrying out the simulation research, did we successfully elucidate and systematize the physical mechanism of a nuclear fusion plasma confinement? Moreover, did we make such academic scientific achievements that foreran the world effort in the research on complex science as a basic research that supports the nuclear fusion research?**

NIFS simulation research has made a number of achievements by explaining various experimental data concerning the magnetic confinement plasmas and developing high-precision numerical schemes that could predict basic characteristics of fusion plasmas. These are published as almost 300 items of original articles. In the summary of the 2006 IAEA Fusion Energy Conference, numbers of achievements were reported. These data objectively support the fact that NIFS simulation research has made quite significant contributions on the international scene. Especially, what they have achieved in the gyrokinetic effects concerning plasma turbulence and structure formation, non-linear behaviors of high-energy particles, high-precision simulations of two-fluid effects, high-resolution magnetohydrodynamics (MHD) simulation, pellet ablation, and plasma-material interaction should be worthy of great reputation. Every one of them is the research closely related to the nature of "multi-hierarchy of physical properties" of nuclear fusion plasmas, and thus, has quite important meanings in various fields of nuclear fusion research including tokamaks and laser fusion. At the same time, these are the pioneering research results that highlight the existence of nuclear fusion plasma research in the new scientific stage called the "simulation science". It is, therefore, highly valued as a result, that NIFS simulation researchers have performed their research with high aims to establish simulation as a new methodology of science.

In the development of the integrated transport code, it is anticipated that NIFS will play a leading role under the active collaboration with universities. Studies concerning plasma complexity and multi-hierarchy property such as fast ignition, peripheral plasmas, and plasma-material interaction are highly motivating researches that are leading in the world. Not only that they are critical topics in the future nuclear fusion research, they also indicate the interdisciplinary relation with many other fields of research; thus, a further development of research shall be much desired for.

[2] To carry out the perspective [1], did we perform the following?

(1) Through the organizational change, did we properly arrange the research platform that was capable of generating intensive research results and also capable of flexible as well as organic management?

Department of Simulation Science as a whole has an academic vision with an idea of "hierarchy" as the keyword. It strives to make a new development of the simulation science by tightly combining the thorough simulation researches that predict behaviors of magnetic confinement nuclear fusion plasmas, laser fusion plasmas, and space plasmas, and development of basic simulation methodologies such as the innovative numerical schemes, virtual reality technology, long-distance broadband network technology, and such. The fact that personnel as well as hardware resources at NIFS were integrated and systematized by establishing the Department of Simulation Science, that consists of the LHD and magnetic confinement simulation Division, the Fusion Frontiers Simulation Division, and the Rokkasho Research Center, is quite meaningful in presuming the future development. The three simulation projects that are carried out in forms that include collaborative researches within and outside of NIFS, have definite research themes in each project; thus, it is much expected that they will become the base to produce intensive research results in the future.

Each of these tasks is interdisciplinary, and further intensification of active collaboration and cooperation with universities and of an organic cross-field collaboration will be much desired for. Then, with a view to further developing a large-scale simulation research by using the next-generation super-computer, a staff training is inevitable; thus, it will be advisable to extend the young researchers organization. Though the computer and network operations were shared between working groups, it will be necessary to clarify the responsibility system for those operations that require special knowledge. Then, it will also be necessary to further intensify the current organization that supports a simulation research environment such as the virtual reality.

[3] As an inter-university research institute, did we actively promote the collaborative research and cooperation with universities that utilizes the analysis device for a large-scale simulation research (Plasma Simulator) and the like? Also, did we contribute to the development of the simulation research?

Numbers of university researchers in Japan utilize the analysis device for a large-scale simulation research (Plasma Simulator) and other devices at NIFS in their collaborative researches. They have made many achievements, largely contributing to the development of simulation research in Japan. Particularly, contributions to the inter-university collaboration

project for the development of an integrated code (TASK) as well as contributions to Osaka University in the laser fusion simulation are worthy of special attentions. The remote on-line access environment from universities was much improved, and the collaborative researches were further promoted. The fact that about 85% of approximately 300 research papers were the result of collaborative research with researchers at universities and other institutes objectively proves that NIFS is making sufficient contributions as the inter-university research institute.

It will be further expected that NIFS should keep on working further to facilitate the usage of computer resources by adopting such project research system that actively utilizes collaboration with universities. Then, it is also hoped for that NIFS should consider wider usage forms utilizing the network system, such as the simulation data sharing and the remote visualization.

[4] Did we successfully play a role as COE? Moreover, did we also play a role as COE in a global sense through international collaborative research and contributions?

Consisting of 21 professional researchers, Department of Simulation Science has made most-advanced research results while developing various themes. The institute succeeded to install and operate the top-class high-performance super-computers in the area of plasma and nuclear fusion. Researches were carried out with active participations of collaborative researchers outside of NIFS. Also, Department of Simulation Science and/or former simulation group hosted, as well as, managed a total of 15 international conferences and workshops in 4 years. Thus, Department of Simulation Science and/or former simulation group have been fully playing a role of an international COE.

NIFS is also expected to work as the international liaison office for the university researchers to participate in ITER and BA. A systematized effort will be necessary so that programs and algorithms developed and maintained in Japan should be utilized as an international standard in the simulation research carried out in BA. For this reason, many attentions are paid to the activities by NIFS simulation science researchers. Also, special budgetary steps will be advisable to request for cooperation with foreign countries.

[5] Through the interdisciplinary collaboration within the National Institutes of Natural Sciences, did we successfully function as an origin for the academic scientific transmission that can also transmit to the research fields other than nuclear fusion?

Roles that the theory and simulation research would play are quite important to give the area of plasma and nuclear fusion the power of transmission of interdisciplinary properties. Starting from the collaboration and cooperation with the area of space and astronomy as well as with the area of molecular science, NIFS carries out positive collaborative activities. This

effort should be valued highly.

The area of plasma and nuclear fusion has vast accumulations of high-level research results. Transmitting those in the form that researchers in other fields could comprehend is expected. Particularly, it seems that the collaboration with areas that originally had little to do with the plasma science; such as molecular science, physiology, and basic biology has been just started. For these areas of discipline, collaborations and cooperation from the methodological rather than scientific approach like a computational method for simulation will be the possibility. The theme for hierarchy-interconnection should come to the center. From now on, looking to the long-term, it is necessary to establish a diverse interdisciplinary network including universities, the Research Organization of Information and Systems, and the Japan Aerospace Exploration Agency.

[6] Did we successfully contribute to fostering of human resources who would play an active part in an international surroundings?

Researchers are making distinguished results in their own field, respectively. Their achievements are given high opinions, internationally. It results from the facts that excellent young researchers are continuously employed, that seminars and academic discussions take place freely at NIFS, and that healthy competitions among researchers exist. Also, NIFS has largely contributed to the technical code improvement of simulation researchers within Japan by preparing various training programs. As for the staff training in the more extended meaning and the creation of a social understanding, broad ranges of NIFS activities such as to host summer schools can be valued highly.

Majority of young researchers in the area of nuclear fusion simulation in Japan belongs to NIFS; thus, NIFS role as the place where PD's as well as young researchers are fostered is extremely important. It is continuously hoped that NIFS shall create a universally open atmosphere for research and that the institute contributes to the staff training that supports a long-term development of nuclear fusion research. Also, NIFS needs to welcome highly capable researchers to this area of research by both concretizing the extension plan for the young researchers organization including specially appointed researchers and proposing the plan to the community. As for the graduate education, cooperation and collaboration to the university educational activities are expected.

[7] Is our future research plan proper? Especially, is the perspective of the mid-/long-term plan properly taken into consideration?

With a grand goal to establish the simulation science in mind, NIFS is drawing a research plan and road map that figure out concrete themes focusing on the *hierarchy*. Their effort on this term can be valued highly. Improvement of their research organization for themes that are

directly connected to the LHD research like creating a road map of the hierarchy-integrated simulation that aims at a prediction for the LHD nuclear fusion reactor model can also be valued highly.

It is necessary to organically connect many research elements for future development; thus, it will become more important to make efforts to positively apply the external knowledge and cooperative researches like a further intensification of the inter-project collaboration and exchanges, collaboration with computer science, exchange activities with other research fields related to non-linear/non-equilibrium phenomena, and cooperation to work in conformity with fusion engineering. Anticipation for the fact that the weight of researches on complexity science is decreasing was also pointed out. It is necessary that NIFS continues to actively transmit and contribute to broad academic fields of research.

[8] Besides the above described perspectives, did we properly resolve the issues pointed out in the 2004 Peer Review and the 2005 Organization Review Committee?

(1) Were the selection of research themes and methodologies by a respective simulation project for the LHD and magnetic field confinement, laser fusion, and plasma complexity proper?

NIFS responded to the issues pointed out in the 2004 External Peer Review and the 2005 Organizational Review Committee and made significant achievements in three fields. Their effort can be highly valued. Especially, their strategy to place importance on particular issues in each field and set up themes is quite appropriate: the importance was placed on hierarchy-extended and hierarchy-integrated simulations in the LHD and magnetic confinement simulation project, FI³ in the laser fusion simulation project, and cross-field collaboration in the plasma complexity simulation project.

Since research in the plasma complexity needs to be carried out from diverse points of views, it will be expected that NIFS shall promote broader collaboration activities. Namely in the case of graphite, the establishment of an advanced simulation method is much anticipated while considering the collaboration with the Institute for Molecular Science. As for the simulation research for laser fusion, too, the construction of more developed research system including the collaboration with the magnetic confinement research will be much expected.

(2) Did we select such research themes that clearly define the contribution to ITER and BA and prepare the appropriate environment?

Research themes are properly determined, like, for example, NIFS is given a challenge on a burning plasma simulation. LHD-NTR (LHD Numerical Test Reactor) and ITER research can be carried out as ones that have academic commonalities. TAE research and high-energy

particle research are said to be the achievement directly connected to ITER. Besides, they contribute to ITER by making contributions to ITPA activities or by participating in the ITER summer school.

In the future, more human resources will be required with a view to working on more research themes including fusion engineering, then making major contributions to ITER/BA. Therefore, NIFS shall need to view in a long-term perspective and consider in detail a particular research system with the Rokkasho Research Center as the core under which they should conduct researches.

(3) While considering the development of research and computer environment as well as the perspective of inter-university collaborative research, did we work on the constitution of the analysis device for a large-scale simulation research (Plasma Simulator)? Then, did we make plans for its operation?

NIFS brings into view the opinions of external collaborative researchers to carry out a device configuration and operation. This can be highly valued. Also, their efforts to activate collaborative researches such as organizing working groups in accordance with research themes, preparation of benchmark-code groups reflecting collaborative researchers opinions, simplification of job classes, improvement in the transparency of collaborative researches by using super-computers, and such, are valued highly.

On the other hand, from the technical point of view in the collaborative research by using super-computer, such computer system is expected that is capable of a seamless collaboration, and that can boost its performance without any major code changes from the university computer environment where the scalar parallel computers are dominant. There is a high possibility of significant changes in super-computer architectures in 2 to 3 years from now. Not that NIFS simply repeats replacing, but it should consider the proper configuration of the super-computer system while assessing appropriate budget and time as well as an overall situation. Thus, an appropriate personnel assignment is also an important issue. Furthermore, a vision, which will effectively utilize the organizational system of the National Institutes of Natural Sciences from the aspect of a multi-purpose infrastructure inherent in a "computer system", shall be required while a BA infrastructure at ITER is also taken into consideration.

(4) Did we present and transmit the research results on the visualization and virtual reality system in order to widely spread research results and promote research collaboration?

Although their achievements gained high reviews, a stronger affirmation on how the virtual reality and visualization helps research will be necessary. A promotion of commonization and standardization₅ of 3-D data format and interface and their presentation,

will be much anticipated from the perspective of the spin-off to collaborative researches and the development of cooperation with universities.

Also, a reinforcement plan for human resources needs to be positively considered. These advanced devices are not necessarily easily remotely accessible from outside. With a view to actively carrying out cooperative research in this field under various usage styles, interactive network communications will become more important. In the future, such efforts as to enable active remote utilizations of various computer resources including numbers of advanced visualizations shall be desired while taking into consideration the acceleration of a network speed as well as significant progresses in hardware and software.

2.1.2 Recommendations

As was stated above, NIFS gained high reviews on the results obtained in their simulation research. Also, their organizational operation system and the academic value of their research plan were valued highly. Now, on that basis, the following issues were requested with a view to further facilitating the development of NIFS simulation research and also to creating stronger cooperation with the domestic and international nuclear fusion science research communities and researchers in related fields:

- (1) In the large-scale long-term research like the development of integrated transport codes, it is expected that NIFS will play a leading role with a view to activating the high potential that nationwide universities possess. Also, since researches in such fields like plasma complexity simulation, laser fusion and peripheral plasmas, and plasma-material interaction bear the interdisciplinary properties to be applied in other research fields, further improvements on organizations and systems are much anticipated in order to further strengthen a cross-field collaboration. Also, management of human resources and systems that support a research environment will be desirable.
- (2) Many of young researchers in the area of nuclear fusion simulation in Japan belong to NIFS; thus, NIFS role as the place where PD's, as well as young researchers are fostered is extremely important. It is continuously hoped that NIFS shall create a universally open atmosphere for research and that the institute contributes to the staff training that supports a long-term development of nuclear fusion research. Also, they need to welcome highly capable researchers to this area of research by showing the extension plan for the young researchers organization including PD's and specially appointed researchers and proposing the plan to the community. Then, it is necessary to secure the career path for young researchers by, for example, enhancing the mobility.
- (3) In order that the simulation researchers in Japan could expand in the entire fields of

nuclear fusion science through the participation to ITER and BA, an research organization and collaborative research system needs to be quickly established.

Chapter 3 Summary

The External Peer Review Committee, toward the formulation of the 2nd Mid-term Plan, considered the current fiscal year as fairly critical in making mid-term reviews for the activity histories in this term. Thus, the committee made reviews for the NIFS two major research fields up to this point: research in the Large Helical Device (LHD) and the simulation research.

It has been almost four years since the current Mid-term Plan has started. Both the LHD research and simulation research have made significant achievements during the term as a result of high motivation of employees and active utilizations of inter-university research facilities in addition to daring modification of the organization as well as prioritized distribution of investment.

In the 2nd Mid-Term Plan for LHD, are expected a steady promotion of projects such as the deuterium experiment to develop the current research activities further, an academic systematization of nuclear fusion science with a view to realizing the nuclear fusion reactor, which is a mission given to NIFS, and achievements that lead the world.

In the simulation research is expected the establishment of simulation methodology to predict phenomena. Accordingly, by forming closer associations with domestic and international nuclear fusion science researchers communities and also with researchers of other related fields, the committee expects that research in wider areas of simulation sciences as the basis as well as the development of the integrated transport code shall be promoted intensively.

At last, the External Peer Review Committee will hope that by reflecting this peer review to the formulation and execution of future plans, the National Institute for Fusion Science shall strive to make further improvements on its research and other operations and thereby play more significant roles than it is now as a central organization of the nuclear fusion research.