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National Institutes of Natural Sciences
National Institute for Fusion Science

NIFS Peer Review Reports in FY2022

March, 2023

National Institute for Fusion Science
Advisory Committee External Peer Review Committee

Contents

Summary

of the External Review Report in FY2022

The FY2022 NIFS External Peer Review Committee (hereafter referred to as “the committee”) held its meetings and hearings from Oct.11, 2022 to Jan.30, 2023 and communicated intensively via E-mail to evaluate the “Human Resource Development (HRD)”, “International Cooperation (IC)” and “Department of Engineering and Technical Services (DETS)”. The perspectives defined by the Advisory Committee are essentially based on the evaluation of the appropriateness and achievement of related activities conducted by the National Institute for Fusion Science (NIFS) as an Inter-University Research Institute, as well as its future direction and strategy, referring to the "Proposal for the Future of NIFS" issued in FY2021.

Two sub-committees were organized. One sub-committee was charged in HRD and IC, and another sub-committee was charged in DETS. They have compiled their reports for each subject, and then the committee worked out the review report from their reports. On the whole, the committee notes excellent contributions of NIFS to HRD and IC in fusion science, and supports by DETS to implementation of research activities in NIFS. On the other hand, the committee shares the concern that to maintain the status quo would lead to shrinkage of these merits.

NIFS is now driving the paradigm shift of its initiative in fusion science towards interdisciplinary development, and the new research system of the UNITs plays an essential role for this reform. It is recommended that NIFS pursues improvement of its world-class research activities and environment in line with this long-term vision. The committee expects that this review is to be helpful for the reform at the present critical turning point of NIFS.

1. Human Resource Development (HRD)

Overall it is *excellent* that NIFS has a high contribution to the human resource development (HRD) to educate graduate students and nurture young researchers as a core institute in fusion and plasma research. The fundamental issue is what role NIFS should undertake as an inter-university research institute in order to advance HRD in whole fusion community including universities. This issue should be addressed in conformity with the new paradigm which NIFS is driving by embodying the UNIT system. It is recommended that NIFS pursues improvement of its world-class research environment to attract the new generation by upgrading research platforms, degree systems, and educational standards by eminent scholars.

The study of fusion and plasma research has an inherently interdisciplinary characteristics as complex sciences regulated by many fundamental physical processes. To resolve key problems for such fascinating subjects, NIFS has explored world-class cutting-edge platforms such as LHD and the super-computing systems, which have been incorporated into the education system of graduate students to become researchers in fusion science.

One is SOKENDAI (The Graduate University for Advanced Studies) , a graduate university based on world class institutions in Japan, and the other is Partner Graduate Schools that graduate students in

universities (Nagoya University, Kyushu University and The University of Tokyo) under supervisors in NIFS. The programs include financial support such as Special Researcher Systems of NIFS and SOKENDAI, which cover 5 years in the graduate course. Particularly, the NIFS Special Researcher System provides support for a total of 5 years including post Ph.D degree, that is, 3 years in the Ph.D course and 2 years in the PD, so that Ph.D students can start their research career seamlessly. Based on these programs, an average of more than 30 excellent students including foreign students, some of whom have gotten DC1 and DC2 JSPS fellowship, have been enrolled every year for these 10 years. These strategic efforts for fostering graduate students and young researchers in fusion science, which have been organized by the newly established "Task Group for Strengthening Young Researchers' Research Capability and Career Path" in the Research Enhancement Strategy Office (RESO), work properly and then are *highly evaluated*.

On the other hand, there is a concern that the numbers of Ph.D students majoring in fusion science and PDs going abroad after graduation is low compared with other leading institutions abroad. The cases of the lack of information on research subjects in NIFS and their attractiveness are conceived. Too much bias of contents and methodologies toward more technical aspects particularly in relation with the LHD studies would lead to an unfavorable factor. It is requested to investigate the reason and to take an appropriate action to devise a contemporary education system.

In addition to the excellent environment of various platforms, a unique advantage for graduate students studying at NIFS is the extensive assigned supervisors of approximately 60 with diverse expertise. While these supervisors are engaged more or less in some form of the HRD, it is thought that NIFS has potential to afford more students. From the perspective of revitalizing research, it is recommended that continuous discussions should be held to build an efficient system to accept more students from Japan and abroad by rearranging various collaboration system with domestic and international universities. The double/dual-degree program in SOKENDAI may be regarded as the next target for further progress of the graduate school education.

One of the primary missions of NIFS is to train young talented researchers to lead the next generation big projects. ITER and JT-60SA are two major international projects. They will start operation in the near future and then require a large number of young researchers for experiments and analyses. They are also important and unique platforms that influences the academic research of high-temperature burning plasmas. Therefore, it is recommended to develop broader partnerships with regard to HRD beyond SOKENDAI and Partner Graduate Schools together with the National Institutes for Quantum Science and Technology (QST) and the ITER organization.

The start of the UNIT system in NIFS and the restructuring of schools in SOKENDAI, which both aims at enhancing horizontal links, are good opportunities to improve NIFS's systems for graduate students and young researchers. Various related programs (summer/winter schools, internship etc.) could leverage flexible development towards other disciplines outside the existing fusion science community, for example, plasma astrophysics, low temperature plasma physics and related engineering. Extension of the horizon of fusion research and attracting researchers of other fields is a key for the young generation to join the field of fusion science. It is recommended that interdisciplinary development of fusion science, which is led by the UNIT system, is incorporated into the HRD together with the above mentioned contribution to fusion energy development.

2. International Cooperation

Overall it is *highly commended* that NIFS has promoted many international collaborations (ICs) as a core international institute and demonstrated excellent global leadership in fusion and plasma research. A new platform succeeding to LHD, i.e., a post-LHD project should be planned as early as possible through intensive discussion in domestic and international communities, where the UNIT system should play an essential key role. This platform is requested to cover a wide range of research subjects and to be superior in flexibility and mobility to pursue the academic fundamentals for fusion science.

One is the ICs using the unique and world leading platforms of LHD and the super-computer system in NIFS. In particular, LHD is the world's first large-scale superconducting system with comprehensive and advanced diagnostics and heating system. It is noteworthy that the diverse knowledge of construction/commissioning/operation obtained from LHD has played a key role in guiding the later large-scale superconducting tokamaks, i.e., EAST (China), KSTAR (Korea) and ITER, and especially the stellarator W7-X (Germany). NIFS has built an excellent remote participation environment for the LHD experiment by developing the auto-analysis system, data repository server, convenient and powerful viewer of data, experiment proposal web system, etc. Engagement of scientific advisors from abroad is also introduced to guide and evaluate research subjects. These frameworks in place contributed successfully to promote IC while they have required significant efforts and dedication. It is highly evaluated that the machine time of the LHD is provided widely to domestic and oversea researches. The total number of proposals has been kept even during the COVID-19 pandemic for several years with the fraction of oversea proposals increasing.

The other is active leadership in planning IC activities with world's leading research institutions and universities currently active in fusion science. Exchange agreements now reaches 32. Multi-lateral programs focused on specific scientific areas such as the Technology Collaboration Program of Stellarator and Heliotron, plasma-wall interaction, and next-generation fusion concepts of Spherical Tori, have been continued under the NIFS leadership under the auspices of Implementing Agreements of International Energy Agency.

These activities have been effectively incorporated with personnel exchanges and planning prestigious conferences and workshops, and have raised fusion and plasma research in domestic universities and institutions to international standards. It should be emphasized that these environments have contributed to foster graduate students and young talented researchers who are expected to be major players in the next generation world fusion program including the ITER project and the Broader Approach (BA) activities. NIFS has contributed to ITER/BA in two ways cooperating with the National Institutes for Quantum Science and Technology (QST). One is through coordination of activities by serving on a project manager and project committee members, and the other is through scientific activities of ITPA for all seven subjects as technical experts based on broad knowledges obtained from the study of complex helical plasmas. These have led to hundreds of jointly authored international publications over the past five years including high impact journals such as elucidation of the difference of confinement between LHD and W7-X.

NIFS has the advantage of deep expertise in 3-dimensional toroidal confinement physics with LHD, related engineering and computational science, which are gathering increasing interest in the world. It is then expected that LHD-based research will resolve fundamental urgent subjects, e.g. multi-scale turbulence, non-diffusive transport etc. should be continued. It is recommended that sufficient

experimental runtimes are shared internationally to ensure relevance of LHD-based research to the global fusion community.

It is noted that a focused assessment of areas for collaboration of NIFS beyond stellarator-heliotron is requested in conformity with the paradigm shift from pursuing only maximization of fusion parameters to more basic and broader fusion science. The new organization of UNITs starts from 2023 in NIFS aiming at interdisciplinary development of fusion science. A new platform succeeding to LHD, i.e., a post-LHD project should be planned as early as possible through intensive discussion in domestic and international communities, where the UNIT system should play an essential key role. This platform is requested to cover a wide range of research subjects and to be superior in flexibility and mobility to pursue the academic fundamentals for fusion science.

Various methodologies to predict and control complex behaviors of fusion plasmas need to be developed based on fundamental disciplines and validated by well-placed multiple experiment devices and computer simulations. NIFS has various collaborative frameworks in domestic and international institutes and universities which have their own platforms. It is recommended that NIFS explores a new type of IC scheme which integrates activities in multiple-platform in NIFS and outside NIFS in order to efficiently resolve unresolved subjects necessary for realization of fusion energy as well as to ensure that fusion science is of particular importance in academic science field. This new scheme/framework is expected to play a key role leading the world fusion science community.

3. Department of Engineering and Technical Services (DETS)

Overall it is *excellent* that the Department of Engineering and Technical Services (DETS) has made essential support to implementation of research activities in NIFS, in particular, the LHD project. Accumulated expertise is a unique property of NIFS as well as the fusion science community in Japan. It is recommended that efficient management of the DETS should be developed in line with the new paradigm of NIFS by making full use of available resources.

The DETS has largely contributed to the deuterium (D) experiment in LHD, which is accompanied by radioactivity due to neutron and tritium, from the preparation phase to the present. The DETS has managed the tritium handling scheme and has done a lot of works for technical preparation and licensing of the D operation in LHD. In addition, the DETS has performed the related education and training to their staff members for the safe and secure execution of the D experiments. These activities have made a significant contribution to the success of the D experiment, which can be regarded as Outstanding. It is recommended that these knowledge, know-how and experiences should be maintained and developed, and will be provided for future international fusion research projects and DEMO.

NIFS has a total of 34 research platforms in addition to the LHD, including a supercomputer (RAIJIN) and engineering research facilities. The DETS supplies technical cooperation and support for these platforms. The DETS also provides technical support through the Division of Information and Communication Systems, the Machinery and Circuit Engineering Department of the Fabrication Engineering Division, and the Central Parts Shop. Many complex systems/facilities are maintained by the limited resources with substantial efforts. All platforms have been operated well, especially for the LHD, which has a very high availability (92.1% since 2017) and reliability (nearly no vacuum leak in recent 10 years). These activities can be regarded as *excellent*. It is recommended that the DETS should

organize and disclose information on developed technologies for future research. In parallel, it is necessary to prioritize and optimize tasks and facilities for efficient contribution of the DETS.

The DETS is working as members of the Safety and Health Promotion Department contributing to the promotion of safety and health in NIFS. The DETS holds an annual "Information Exchange on Occupational Health and Safety Meeting", which provides valuable opportunity for participants from universities and research institutes to exchange information. These activities are regarded as *excellent* and should be continued.

For the technical exchange with technical staff from universities and research institutes nationwide, the DETS conducts various technical supports such as analysis technology using the finite element method ANSYS and NC machining technology, and organizes related technical workshops. These activities are regarded as *excellent* and should be continued. It is desirable that the DETS will further strengthen its technical cooperation with universities and research institutes.

It is Commendable that The DETS promotes industry-academia collaboration by using their accumulated knowledges such as dissimilar metal bonding technique. It is recommended that DETS increases their collaboration with industry more and enhances spin-off benefits from fusion engineering technology to various other fields. This could advance fusion engineering technology in turn.

In the past five years, about 20% of the technical staff has been replaced. The DETS has provided appropriate training programs to young staff members for generation change. The DETS also encourages them to participate in training opportunities outside of NIFS, including international joint research. One technical staff was selected for the "PM Development and Promotion Program" of the JST and one ECH technician from DETS transferred to the ITER organization. These activities are regarded as *excellent* and should be continued.

4. Additional Suggestions from the External Peer Review Committee

The committee, in constructive spirits, suggests that the following issues should be considered for review in the future.

1) NIFS is driving the paradigm shift to extend the horizon of fusion science. The new research organization employing the units will start in FY2023. These units are formed involving researchers outside NIFS through thorough discussions in the community and challenge unresolved critical scientific subjects related to realization of fusion energy as well as energy circulation in nature through interdisciplinary approach. The progress on this reform and the activity of the units should be reviewed at the right time. Also the activities in NIFS such as HRD, IC and DETS reviewed this time should be aligned with the reform. Therefore, these three should be revisited some time in the future.

2) Research platforms which include not only experimental facilities/devices but also super-computing environment and use of data are critical elements for collaborated research. It is an essential role for NIFS as an inter-university research institute to provide the world-class platforms for joint use to the community.

3) The collaborative research is the primary mission of NIFS and the strategic rearrangement of its system would be inevitable for the positive synergy with the new research organization. The collaboration system will be an important subject for the external review.

4) The contribution from NIFS to the R&D towards the realization fusion energy represented by the ITER project and the Broader Approach activities is highly expected. The role of NIFS is complementary to QST and the academic commitment of NIFS to convince the relevance of fusion energy is very important.

5) Even if the LHD design is not carried forward as a possible reactor concept, NIFS is expected to play a central role in advancing the understanding for helical fusion reactors through the outstanding characteristics of the well-controlled LHD plasmas and the excellent array of plasma diagnostics. Contribution to the design of fusion reactors of NIFS shall be assessed from broad perspectives.

6) Contribution and cooperation regarding the safety and health initiatives, which has been reviewed specifically for DETS, are established by the integrated activity in NIFS. It is recommended that these items will be reviewed as a whole of NIFS on the next occasion.

Main Body

of the External Review Report in FY2022

1. Human Resource Development

Overall it is *excellent* that NIFS has a high contribution to the human resource development (HRD) to educate graduate students and nurture young researchers as a core institute in fusion and plasma research. The fundamental issue is what role NIFS should undertake as an inter-university research institute in order to advance HRD in whole fusion community including universities. This issue should be addressed in conformity with the new paradigm which NIFS is driving by embodying the UNIT system. It is recommended that NIFS pursuits improvement of world-class research environment to attract new generation by upgrading research platforms, degree systems, and educational standards by eminent scholars.

Perspective 1

Through graduate school education in SOKENDAI and cooperative universities, has NIFS fostered scientists and engineers who will lead fusion research and development ?

Findings/Evaluation

- **Overall evaluation**: NIFS aims to develop general science and engineering scholars who have acquired a wide range of knowledge and skills that can be used not only in fusion-related fields but also in any other fields. From these viewpoints, NIFS has been successful in fostering and producing scientists and engineers through graduate school education and various education programs, and contributed significantly to the human resource development in the plasma and fusion science research. Especially, is can be seen that NIFS is the core in education for fusion science.
- **Graduate school systems**: NIFS has been educating graduate students in the department of fusion science in SOKENDAI, the graduate university based on national institutes in Japan, and produced 5 Ph.D. per year on average during 30 years, i.e. total number is 150. In addition to SOKENDAI, NIFS provides a nice framework through the collaboration with universities in the graduate school education, i.e. Partner Graduate Schools which include Nagoya University (two departments), Kyushu University, the University of Tokyo (two departments). It should be mentioned that the number of the students belonging to the activity is about 17 per year on average in the period from 2010 to 2021.
  - ✧ In the period from 2010 to 2021, almost 91% of the capacity in SIKENDAI, i.e. 19, is filled with about a half (44%) being the students from abroad.
  - ✧ It is highly appreciated that the total number of students, both for SOKENDAI and Partner Graduate Schools, is increased even in the period of COVID-19 due to implementation of secondary examination, and enhancement of public relations.
  - ✧ The fact that there are about 10 students (researchers) who got DC1 and DC2 scholarship of JSPS from 2018 to 2022 on average. This number is relatively large for the quota in SOKEDAI and then reflects the excellence of the students studying at NIFS
  - ✧ The start of special researcher system by NIFS, i.e. the financial support system, started from

AY2020 (3 years for Ph.D and 2 years for PD) is also appropriate.

- **Various education programs**: NIFS has also promoted human resource development from a broader perspective through multiple programs such as ASIAN Winter School (average 42 students per year from 2010 to 2019), special joint-use program for domestic and foreign students (average 14 students per year from 2010 to 2021 for COVID), and domestic and international internship system (944 students times days per year on average from 2011 to 2022). Especially. The internship programs are highly active, because more than 25 students were enrolled in the programs from 2015 to 2019.
- **Contribution of NIFS staffs :** The number of research staff who can be involved in education is around 60. Considering the number of graduate students and those who participate in various education programs, almost all staffs are considered to be involved in some form of human resource development.

Recommendations

- **Number of Ph.D. students**: There is a concern that the number of Ph.D scientists who major in plasma and fusion science in Japan is not large but rather small, so careful analysis is necessary. The internship system is highly evaluated as a method of increasing young talented researchers who will work in Japan in the future. The committee recommends that these internship students should receive research support from the institute in terms of software and hardware.
- Considering that there are 60 research staff who can be involved in education, it is thought that there is room to accept more students. From the perspective of revitalizing research, the committee recommends that continuous discussions be held on building a system to accept more students from Japan and abroad in collaboration with universities. The double-degree or cotutelle program may be regarded as the next target for further progress of the graduate school education.
- **Information and attraction of research subjects and education course:** The information on the research subjects, including how they are decided for each student, is unclear, while it seems that the subject is chosen based on the student's interests and skill, and on the advisor's expertise in the course. The titles of the doctor theses are listed on the web (https://soken.nifs.ac.jp/en/archives/education/theses). These titles give an impression that the themes contained in the theses seem to focus highly on the technical aspects, particularly in relation with the LHD studies. The tendency of the subjects tilted towards the technical aspect is also seen in the titles of the special lectures for graduate school. If we look at the course titles in FY2022, most of them look highly technical and aiming at teaching skills for particularly in fusion sciences. Among these technical subjects are seen few mathematical and physical subjects. However, they look either incompletely general or over-specialized. It is recommended that NIFS should work out the approach to improve information and attraction of research subjects and educational course.

Perspective 2

Has NIFS advanced human resource development for young people in Japan and abroad, not only in the narrow sense of fusion science, but also in terms of interdisciplinarity and its exchange ?

Findings/Evaluation

- **Overall evaluation**: Plasma and nuclear fusion research by their nature are interdisciplinary characteristic of complex and comprehensive sciences that includes many physical and engineering aspects. Based on this concept, NIFS accepts large number of graduate students and supports domestic and foreign young researchers by planning various education and research programs to

expand their opportunities by learning skills and applying them outside of fusion science. An example of this is laser development research beyond that used for plasma measurement. NIFS has a variety of internship programs of short and long duration and schools, at NIFS and beyond. Internships at NIFS may expose students to senior researchers for a short duration or they may lead to extensive education in a particular area. An example of a school is that held by NIFS in Thailand that attracts students from different backgrounds (graduate school, colleges, technical schools) and both domestic and foreign countries. These wide-ranging HRD efforts at NIFS are highly evaluated.

- **Research subjects and interdisciplinary aspects:** On the other hand, the committee recognizes that at NIFS, the research subjects have concentrated more on project-oriented problems for achieving higher fusion performance, and that the point of achieving systematic and proactive promotion of interdisciplinary research activities outside the fields of nuclear fusion has not been necessarily strong but rather weak.
- The committee is also concerned that only a small number of Japanese students go abroad after their graduation. Furthermore, the number of domestic PD researchers is small. Particularly, JSPS PD research fellows have been none for more than these five years.

Recommendations

- **Promotion to interdisciplinary research system：** The committee considers that implementation of the UNIT system at NIFS and the restructuring of SOKENDAI would be good opportunities to modify and diversify NIFS's postdoc and collaboration systems towards more open and flexible directions. More efforts, e.g. introduction of some specialized frameworks, should be made to attract young talented students and researchers and to promote interdisciplinary researches by strengthening collaboration with outside world.
  - ✧ Possible modification would be to include fortifying the joint use programs and internships by widely opening for other branches of academic fields, for example, in plasma astrophysics, low temperature plasma physics and engineering technologies as well as in more academic subjects. Adding a school component at its beginning should be an effective way to provide a big picture on plasma's wide relevance and application both in science and technology.
  - ✧ Also, the winter and summer schools, which has moved to Thailand, and joint seminars could be improved to increase domestic participants. Moreover, the SOKENDAI is planned to be a single graduate school in April 2023. The structural change may enhance horizontal links with other departments to help NIFS accelerate inter-disciplinary education and research.

Perspective 3

Are there any efforts to support young researchers, including those of postdoctoral fellows and assistant professors, in starting and developing their research ?

Findings/Evaluation

- **Overall evaluation**: Overall, the committee highly evaluates that NIFS has taken a number of steps to support young researchers, including the establishment of the "Task Group for Strengthening Young Researchers' Research Capability and Career Path" in the Research Enhancement Strategy Office (RESO) program. Even at the moment, the committee recognizes some emerging attempt by young researchers to extend the scope of their work from the titles of the accepted research programs.
- **Supporting system for young researches:** NIFS had provided a number of systems which supports young researchers to start-up their ideas before obtaining external funding by providing them research and travel expenses. The system includes financial support systems, such as NIFS special

researcher system over 5 years (3 years for Ph.D students and 2 years for postdocs) and SOKENDAI special researcher system also over 5 years, which are designed for a career path to ITER and other research fields. Moreover, it is very unique that NIFS has special joint-use program in which NIFS staff supervise students.

Recommendations

- **Number of PD researches and improvement:** As of the postdocs at NIFS including JSPS fellows, there are typically between 7 and 12 researchers, with nearly all of them coming from overseas. Interestingly, very few Japanese researchers apply for postdoc positions at NIFS. This phenomenon is acknowledged by NIFS staff and it would be beneficial to investigate the reasons for the low number of Japanese postdocs at the institute. In that study, NIFS should also focus on issues of gender imbalance and diversity in the field. There was also a suggestion to appoint special NIFS fellows as a part of RESO or outside of RESO to raise the profiles and attract more applicants, but this is an optional recommendation.
- **Maintaining Research Environments**: NIFS has achieved significant research progress utilizing its world-class helical system, the LHD, and extensive simulation resources. However, it is anticipated that the research funding environment may become more challenging in the future. It is vital to preserve the current research resources and continue to improve upon them to enable young researchers to conduct world-class research.
- If financially feasible, the committee also recommends expanding the special joint program, possibly over multiple years as it is not easy to make substantial progress only in a single year. This effort will be crucial in building motivation and potentially advancing their career goals.
- On the other hand, it is too early to fully evaluate the impact of the launched initiatives to support young researchers, but the committee recommends to maintain these activities for a longer period, with periodical review for improvement and outcomes.

Perspective 4

Has NIFS provided a world-class research environment where young researchers can take the first step in their career path after obtaining a Ph.D., and where students who aspire to become researchers can be nurtured ?

Findings/Evaluation

- **Overall evaluation**: NIFS has lead world top level research and educational environments for both hardware as well as software, which has provided the first-rate research opportunities in experiment, computation, and theory. Indeed, they can be an initial excellent career path to be a researcher in plasma and fusion science, and then are *highly evaluated*.
- **Excellent facilities and platform:** NIFS has provided world-class excellent facilities, such as Large Helical Device (LHD), one of the large stellarators in the world as Wendelstein 7-X, supercomputer, superconductivity development research, and so on. Especially, the most excellent feature of LHD is that it has the finest diagnostics environment comparable to or even beyond the leading tokamak experiments, thus LHD is considered, with no doubt, as an excellent research environment for young researchers.
- NIFS also provided the Plasma Simulator, “RAIJIN”, the world’s top-level supercomputer and has played a central role by providing unique opportunities to domestic and international plasmas researchers for evaluating and predicting complex behaviors of wide class of plasma physics and related applications, including fusion plasmas and those in LHD. Based on the super computer system, NIFS has explored a

wide range of theoretical and computational methodologies and constructed key codes.

- These facilities have provided an excellent environment for training students aspiring to be researchers, which are *highly evaluated*.

- **Excellent human resources:** In addition to the above-mentioned excellent facilities, it should be mentioned that one of the positive and unique characteristics of education system of NIFS could be that a large number of professors of different majors can participate in training a student. The feature is considered to provide an excellent environment for fostering researchers needed for fusion science which requires integrated knowledge of science and technologies covering wide disciplines of academic field.

  Support system of student and young researchers: NIFS has made efforts to establish systems to support students financially by using the Task Group for Strengthening Young Researchers' Research Capability and offered various interesting programs, such as NIFS special researcher and SOKENDAI special researcher systems. The former and latter are, with both giving financial support for five years, for students, including postdoctoral positions, in Japanese universities and for SOKENDAI students, respectively, which are designed for a career path for ITER and other research fields. Moreover, NIFS has established Career Path in Research Enhancement Strategy Office (RESO) and begun supporting the start of developmental research plans since FY2021. These efforts should be *highly evaluated*.

Recommendations

- **Two academic frontier environments:** The quality of the environment at NIFS critically depends on the platforms and research topics that NIFS offers. LHD is the primary facility of this sense. Thus, it is strongly recommended that NIFS should make strategies to maintain academic frontier environment, not necessarily in size scale, for the post-LHD phase in the future.

- **Improvement for education and research topics:** In the graduate and the post-graduate education at NIFS, there seems room for further improvement on two points; openness of the information on the education process as well as the career paths, and flexibility of the research contents and methodologies.

  ✧ **Education system**: From a world-wide viewpoint, the education system at NIFS seems to be holding the old-fashioned style which would concentrate more on closed and rigid job training, in contrast with the superb research environment with LHD, supercomputers and superconductivity development research.

  These features are manifested in the situation that there is no JSPS-PD accepted since 2017 and that fraction of Japanese post-docs is in a trend of decrease in the same period. These may suggest that any problem might be inherited in the current organization of NIFS or Japanese plasma-fusion community, therefore, careful and detailed analysis is recommended. The committee recommends that this situation should be improved as soon as possible to invent a contemporary education system by incorporating the UNIT system that NIFS is introducing.

  ✧ **Seamless training system**: Moreover, it is recommended that NIFS should make other frameworks to train internationally active researchers, such as one to accept graduate students who finish the international internship as PD researchers, and one to have Ph.D students work at foreign institutes after obtaining his/her degree. It is because there appear to be almost no such students and PD researchers.

  ✧ **Connection to wider academic fields:** Moreover, on the occasion of launching the UNIT system, NIFS should broaden its academic connections and researchers' carrier paths of young researchers to other academic branches outside the plasma physics and fusion science, vice versa attracting researchers of other fields to join the field of plasma and fusion science.

✧ **Connection to world-level project-oriented research:** It is a primary mission of NIFS to supply young talented researchers who will work in the field of plasma and fusion science, and particularly for the present and future fusion projects, ITER and JT-60SA, which require a large number of researchers. In this sense, it is recommended to establish broader partnerships beyond SOKENDAI and University joint-use program, for example, one with QST in human resource development.

2. International Cooperation

Overall it is *highly commended* that NIFS has promoted many international collaborations (ICs) as a core international institute and demonstrated excellent global leadership in fusion and plasma research. A new platform succeeding to LHD, i.e., a post-LHD project should be planned as early as possible through intensive discussion in domestic and international communities, where the UNIT system should play an essential key role. This platform is requested to cover a wide range of research subjects and to be superior in flexibility and mobility to pursue the academic fundamentals for fusion science.

Perspective 1

Has NIFS taken the initiative in international research activities?

Findings/Evaluation

- **Overall evaluation**: NIFS has provided excellent international leadership and promoted many international collaborations. It is appreciated that NIFS plays a leading role in fusion research as a core international institute in various aspects. Of note are NIFS's achievements in research itself under various frameworks of international collaborations, such as experimental research using the helical device LHD and large-scale supercomputer simulation.
- C**ontribution using facilities and leadership in wider fusion community**: It is praiseworthy that NIFS has provided many international researchers with the opportunities to utilize the facilities even under the constraints due to COVID-19 pandemic. Moreover, NIFS is expected to continue this leadership role in ongoing and future fusion projects. Because of the experience of constructing a large-scale super conducting machine prior to EAST in China, KSTAR in Korea, and Wendelstein 7-X in Germany, NIFS has played an important role in leading a large scale superconducting steady state machine, which was the first complex helical system in the world.
- **Contribution for serving major international conferences and journals**: NIFS has played important roles in prestigious conferences and workshops on the fusion science. For example, NIFS organized (with Japan as the host country) the 26th IAEA Fusion Energy Conference, the main international conferences on fusion research. In addition, it is remarkable that NIFS has continuously hosted (31 times) the annual international Toki conference. It is also commendable that many NIFS researchers have contributed to the administration of other various international conferences and representative international journals involving fusion science. NIFS scientists have served as program committee members for 23 conferences for 10 years or longer, and as editors of 12 international academic journals.

Recommendations

- **New attractive projects leading international fusion and wider science community:** With the change in strategy for LHD (from fusion parameter advancement to more basic fusion and plasma science) it becomes necessary for NIFS to proceed with new projects and to attract researchers of wider scientific fields. This would position NIFS for a leadership role in the future international community of fusion science, and would also provide domestic students with opportunities to find

their international career path after their doctoral course.

- Also with the change in lab strategy, a focused assessment of areas for collaboration for NIFS beyond stellarator-heliotron should be carried out. Developing a decadal plan to project where NIFS should be in 10 years in both plasma physics research and fusion science/technology research is anticipated to help this process. This could also serve as a guidance for the upcoming UNIT system. NIFS is expected to provide the leadership not only in the existing conferences and publications, but also in participations and discussions in these new and wider across fields.

Perspective 2

Has NIFS been able to promote systematic academic exchanges with highly competitive foreign research institutions, and continuing world-class collaborative work among researchers as a result of such exchanges ?

Findings/Evaluation

- **Overall evaluation**: NIFS has maintained multiple exchange and collaborative programs with the leading institutions and laboratories active today in fusion and plasma science. These programs have stimulated plasma and nuclear fusion research in Japan.

- **International collaboration programs with highly reputational institutions:** The programs include collaborations with Europe, Asia, and the US. Specific collaborative programs are in place for work with China and South Korea. Other collaborative programs, which include several nations, focus on specific scientific areas: stellarator-heliotron, plasma-wall interactions, and spherical tori.

  Through these international joint collaborations, NIFS has constructed strong relationships with the world's leading research institutes, such as PPPL, GA, and IFS in the US, SWIP and ASIPP in China, and KFE in South Korea, etc. The emphasis may differ with different institutions, for example, more on diagnostics with Korea and more on system engineering with China. Such differences can be taken as strategic, as the goal of collaboration is to build on each other's strengths. Overall, there are 32 academic exchange agreements in place. These have led to hundreds of jointly authored publications over the past five years.

- **Global leadership of NIFS on TCP:** In addition, NIFS has led the long-term global leadership of the technology collaboration program (TCP) of the Stellarator and Heliotron (ST) using LHD-based research activities. NIFS has also promoted wider international collaborations on fusion engineering and technologies, including plasma-wall interaction science and next-generation fusion concepts of Spherical Tori (ST). The establishment of partnerships and cooperative relationships with world-class international research institutions has greatly contributed to the fostering of domestic graduate students and young talented researchers who could sustain the next generation world fusion program including ITER.

- **NIFS under the pandemic:** It is remarkable that NIFS was able to increase collaborative experimental runs on LHD during the pandemic, with international partners participating remotely. This required effort and dedication. As a result, the number of published international collaboration papers increased in spite of the COVID-19 pandemic. This shows that the frameworks in place contributed significantly to promoting the international research activities of NIFS.

- **Decreasing trend for collaborations:** On the other hand, since 2020 there has been a significant decrease in human exchanges with foreign countries due to the impact of COVID-19, which is desired to be improved in FY 2023. Related to this decrease, there are some concerns, because the decrease seems to have started during the period 2017 to 2019 even before the pandemic, especially for Japanese researchers visiting foreign institutions. It is possible that the decrease was due to the

start of the DD experiments on LHD. The balance between project research activities, which sometime require investment of a lot of resources, and fundamental research activities from a broader perspective should be carefully organized.

Recommendations

- **Role of NIFS in Japan:** The official collaborations include fusion scientists and laboratories in Japan generally, not just in NIFS. Therefore, NIFS should continue to be an extremely valuable collaborator in the world plasma and fusion science and play a central role for future fusion programs through its national leadership, exploiting its unique facilities.
- **LHD-based collaborations in the future and beyond:** The change in strategy for LHD (from fusion parameter advancement to more basic fusion and plasma science) might have two effects on future collaborations. Its retreat as a fusion parameter advancement facility could reduce its attractiveness somewhat, particularly as other labs (and private companies) focus on rapid results with new experiments. On the other hand, since it is not pushing parameters, there is more experimental runtime available on LHD, which makes it more attractive for international collaborators. Indeed, it is reported that incoming collaborations with LHD remain very strong, and have actually increased recently. It should be continued in the future as well.
- Future collaborations can continue to build on the strengths of NIFS in plasma computational science and stellarator-heliotron physics. Stellarator-heliotron is gathering increasing interest in the world, which should continue to assure the relevance of LHD to the world fusion community. The database of LHD and W7-X in Germany, which are the two largest, most capable stellarators in the world, remain for the next decade. Joint studies including possible experiments between the two facilities will continue to be productive.
- In the stressed financial situation of LHD, NIFS will need to entrain human resources besides those of the LHD or supercomputer facilities. For this purpose, NIFS can organize international schools, in particular in Asian countries, or organize science-oriented international workshops on broader subjects in fusion and plasma science. It will be also effective to utilize a cross appointment program with other institutes, starting on the domestic level.
- **After COVID-19:** Since the pandemic restrictions are easing, the jump-starting of in-person collaboration is highly desirable, not only on the topics centralized on the LHD but broadly on all relevant important/interesting scientific topics. NIFS should promote in-person collaborations which are essential for young researchers to develop their collaboration networks that influence their futures.
- **Critical examination of collaboration projects:** The planned result-based (goal-oriented) re-evaluation of existing and new collaboration agreements is excellent. Many collaborations are easy to get started but are difficult to achieve outstanding results that are otherwise difficult to achieve without collaboration. Critically examining collaboration projects (including more detailed reports on the resultant achievements) and placing resources with focus is recommended, especially when NIFS will be under financial stresses. In order to evaluate projects objectively, external reviews of proposed collaborations are highly desirable.

Perspective 3

Is NIFS contributing to ITER and BA activities ?

Findings/Evaluation

- **Overall evaluation**: The ITER project and the BA activities are national projects for the future energy under a collaboration framework with QST since 2013 and also with industries. NIFS has played a leading role in the Fusion Energy Forum of Japan as the membership of NIFS scientists in

multiple groups in two ways.

- ✧ One is through coordination activities in the ITER-BA Collaboration Subcommittee established in the Collaborative Research Committee and outsourcing of ITER operations. In particular, NIFS researchers have been appointed as a project manager, project committee members, and steering committee members, making significant contributions in terms of management.

- ✧ The other is through scientific activities since many researchers from NIFS actively join the 'topical groups' to solve the physics subjects of ITER ITPA as technical experts, based on their knowledges and experiences. Especially, in order for fusion reactors including ITER to be accepted by wider societies especially in academic science field, it is necessary to develop methodologies that predict and control complex behaviors of high-temperature confined plasma based not only on empirical scaling but also on scientific backgrounds validated by fundamental experiments as well as first principle computer simulations. In this viewpoint, NIFS contributions to ITER ITPA are valuable because NIFS can provide wider views to the ITER/BA researchers based on the expertise of stellarators while many studies have been limited to tokamak.

- ✧ The concrete examples that NIFS contributes to ITER activities are given as follows,

  - ▪ Participation to the ITER-Like Wall (ILW) experiment and analysis of material samples on the JET tokamak and the dust analysis.

  - ▪ ITER superconducting coils, and modeling of the ITER cooling system.

  - ▪ Developing data transfer technology to access the ITER site, which achieves the new world record of inter-continental long transfer.

- ✧ Number of papers have been published regularly as the outcome of the ITER/BA activity. Due to above wide activities, the contribution of NIFS to the ITER and BA activities is significant and then excellent.

Recommendations

- **Academic contribution to ITER/BA activities**: Through research activities to generalize and universalize results that have been acquired in the past LHD research, NIFS is expected to play a major role even in the development research directly connected to the ITER project and the BA activities by clarifying key unsolved problems in nuclear fusion and providing solutions for them. Therefore, it is anticipated to promote the academic contribution to ITER and BA by NIFS, and continue the participation to the state-of-the-art technologies as one of platform to progress academic research in Japan by incorporating UNIT activities which start from FY2023 at NIFS. Especially, the inter relation between tokamak and helical system in terms of wider plasma physics and engineering should be continuously explored.

- **NIFS role of HRD for long term fusion programs**: It is expected in near future that the ITER project with the BA activities should need more human resources, which should be provided from NIFS and universities. From this viewpoint, it is highly desirable to continue and strengthen the contributions by continuing and increasing effective collaboration with QST as both ITER and BA will be intensifying in the coming years and can provide excellent opportunities for young researchers in Japan. For this purpose, NIFS not only contribute to ITER and BA, but also need to make much use of broader results and understandings of ITER and BA, which includes those from other participating countries. Such efforts could broaden the perspective of NIFS and show a new career-path for young researchers.

- **Wider information of for ITER/BA:** From the perspective of NIFS leadership leading nuclear fusion research in Japan, it is important to make the community more aware of the organizational efforts based on fundamental academic research by NIFS for the ITER project and the BA activities. The dissemination of the scientific contribution of NIFS to the ITER-BA should be enhanced via efficient media such as a website in order to increase opportunities for the participation to the related

research activities. It is recommended that a framework to make the role of NIFS public is to be accommodated.

Perspective 4

Is NIFS promoting international joint research using research platforms ?

Findings/Evaluation

- **Overall evaluation**: NIFS has various kinds of excellent collaboration programs using platforms of their own, such as LHD, super-computer, facilities of super conducting and cryogenic systems, and so on. It is highly evaluated that the 'machine time' of these platforms is provided widely to domestic and oversea researchers, and that the total number of proposals is nearly constant, even during the COVID-19 pandemic, for several years, with the fraction of oversea proposals increasing.
- **New collaboration schemes**: To proceed the collaboration using platforms efficiently and productively, it is highly evaluated that NIFS have explored the new cooperation system by assigning overseas advisors, introducing automatic calculation systems, installing repository servers, web experiment proposal etc., in order to facilitate the implementation of these proposals.
- **Key collaboration outcome using platforms:** The NIFS platforms are effectively utilized in the development of active international collaborative research, including various international projects and academic exchange agreements in which NIFS is the implementing agency. From all the above, it appears that the development and use of research platforms is outstanding. Typical examples are given as follows.
  - ✧ **Key joint researches using LHD:** The primary platform of NIFS, LHD, is one of the large stellarator-heliotron in the world. The LHD facility can provide a perfect platform due to its systems of comprehensive diagnostics and reliable operation of heating. Owing to recent efforts represented by the remote experiment environment (including web experiment proposal etc.), the number of research proposals increases from overseas since FY2017. Thanks to international joint research, many excellent results have been published in high-impact journals. The examples include collaborative works on the comparison with dependence of turbulence on configuration (F. Warmer et al., Phys. Rev. Lett. 127 (2021) 225001) and positive effects of boron power injection (F. Nespoli et al. Nat. Phys. 18 (2022) 350).
  - ✧ **Key joint researches using simulator and develops codes:** NIFS also provides superior environment for simulation works with an excellent supercomputer. Moreover, a simulation code named MEGA has been developed in NIFS. The code is used worldwide in various institutes, such as General Atomic (U.S.A.), Max-Planck Institute (Germany), Seville University (Spain), and so on. The code has supported publishing excellent papers.
  - ✧ **Key joint researches on various fusion technologies and academics science:** Moreover, in the aspect of the fusion technology and engineering, NIFS provides a platform to collaborate with constructing ITER superconducting coils, and modeling of the ITER cooling system. Furthermore, it should be mentioned that atomic and molecular database that NIFS constructed and developed is opened to public, and highly recognized in active participation to IAEA and EU activities. The database is extended to the opacity data of high Z ions for estimating the emission intensity from Kilonova. In addition to the above-mentioned platforms, data-transfer technology is developed for international collaboration using overseas platforms including Wendelstein 7-X (Germany), EAST (China) and CFQS (China). It should be noted that the system achieved a new world record (at that time) for intercontinental data transfer.

Recommendations

- **Successive plan of LHD**: The primary platform, LHD, cannot be operated forever. It is strongly recommended that a successive plan of LHD should be made for productive research based on the new UNIT system as early as possible. One of recommendations for future substitute of LHD, taking into account the present situation in Japanese academic finance, is that NIFS should consider a cost-effective platform that is superior in flexibility and mobility in order to pursue the academic fundamentals for plasma and fusion science.

- **Leadership based on computational platform**: As for the supercomputer that NIFS owns, it is recommended that the machine time should be opened more widely for other academic disciplines to form fundamentals of fusion science, although it is obvious that it contributes directly to fusion science, for example, through providing the MEGA code world-wide for fusion community.

- **New platforms leading academic science and fusion program:** As for other platforms, NIFS should not only organize them along the purpose of the new research system, *i.e.,* UNIT system, but also should be active to make new platforms to pursue the academic fundamentals in science and technology, *e.g.,* magneto-hydrodynamics, turbulence, velocity space dynamics, superconducting, heat handling, material-plasma interaction, and so on, and also to lead coming international historical experiments such as ITER and JT-60SA.

- **Role to integrate wider domestic and foreign platforms**: NIFS has various collaborative frameworks domestic and international institutes and universities that may have their own platforms. The committee recommends that NIFS should make these frameworks stronger, and should integrate outside platforms into NIFS activities. The integrated platforms can be used for the community to produce scientific outcomes of plasma and fusion science, and its related fundamental disciplines.

Perspective 5

Has a system been established to facilitate international joint research ?

Findings/Evaluation

- **Overall evaluation**: With the aim of smoothly carrying out a wide range of collaborative research activities, NIFS has developed international joint research systems that include domestic universities and other institutions, that plans and proposes collaborative research, that publish and utilize research results, and conduct support activities.

- **Extensive collaboration research frameworks**: NIFS has so far focused on steady state high-temperature plasma research for nuclear fusion utilizing platforms, 1) LHD, 2) simulation, 3) superconducting and cryogenic systems, 4) atomic and molecular database, 5) data transfer technology, and has gotten unique and comprehensive outcomes. Those results have provided an important academic basis for fusion reactor development including in the ITER project and the BA activities.

- Based on such a wide range of research activities and achievements, NIFS has a long history for facilitating the international joint research. Especially, the international collaboration framework utilizing LHD has significantly progressed by developing schematics of remote participation and produced key outcomes by publishing them to high IF journals. These series of activities are highly evaluated.

- **Hard and soft-ware systems for international collaboration**: In addition to bilateral inter-governmental ones and IAEA technology collaboration program, such as US-Japan collaboration program, etc., NIFS has established some other systems for international collaboration. The systems include remote participation in LHD experiment, open database (repository server) such as 86TB

for LHD experimental data, as well as establishing systems such as the Committee for Coordinated Research, International Collaboration Section, and Administration Division and International Relations Committee. These programs appear to be successful since the number of published international collaboration papers has increased in spite of the COVID-19 pandemic.

- Therefore, the present system of NIFS has worked well for facilitating international joint research activities based on the existing facilities of LHD and the supercomputer. In addition, NIFS is handling adequately the export control of both materials and knowledge, although the international political affairs are getting complicated recently.

Recommendations

- **Corporation with NIFS UNIT system for international collaboration**: Since NIFS has developed the excellent international joint research system, NIFS should incorporate this system into the UNIT System, which starts from FY2023, effectively.
- **Toward new types of collaboration based on new visions**: On the other hand, there are no clear proposals for the future in the presentation under the shrinking situation of LHD, in particular, how the new vision of NIFS is realized. The systematics of platform based international collaboration which have successfully worked in LHD are desired to be expanded to other platforms. It may be necessary to create a new strategy to appeal the human resources of NIFS to the world and to launch a new type of international and domestic collaborations for realization of the new vision of NIFS.

3. Department of Engineering and Technical Services

Overall it is *excellent* that the Department of Engineering and Technical Services (DETS) has made essential support to implementation of research activities in NIFS, in particular, the LHD project. Accumulated expertise is a unique property of NIFS as well as the fusion science community in Japan. It is recommended that efficient management of the DETS should be developed in line with the new paradigm of NIFS by making full use of available resources.

Perspective 1

Has the DETS (Department of Engineering and Technical Services) contributed to the preparation and implementation of the deuterium experiment (plasma performance improvement) in the LHD ?

Findings/Evaluation

- The DETS has largely contributed to the deuterium experiment in LHD from the preparation phase to the present, leading to great success of the experiments.
- The DETS has managed the tritium handling scheme and the related education of their staff although NIFS had little experience of the tritium handling before the deuterium experiment.
- Before the deuterium experiment, the DETS has done a lot of works for licensing of the deuterium operation in LHD by preparing the safety facilities and the documents which were required by the regulatory authority.
- The DETS greatly contributed to the preparation for deuterium experiments at LHD, such as calibration of neutron measurement, countermeasures against neutron leakage, maintenance of the exhaust system, and updating of the access control system.

- The DETS established an original comprehensive radiation monitoring system that enables centralized monitoring of measurement data and operational status including tritium concentration measurements at the boundaries of the controlled area.
- Training of 11 personnel as Class 1 Radiation Handling Supervisors has made a significant contribution to the safe and secure execution of the deuterium experiments at LHD. In addition, the technical staff played an important role as instructors of the training on the handling of tritium in the radiation-controlled area.
- The achievements mentioned above represent a vital contribution to the success of deuterium experiments in the LHD and can be regarded as *Outstanding*.

Recommendations

- As the deuterium experiment in LHD is quite significant for fusion energy development, knowledge, know-how and experience are necessary to be maintained and developed. It is recommended that NIFS should enhance the research in this field and transfer the precious knowledge to the next generations.
- It is recommended to identify technologies developed through the deuterium experiments that could be utilized in future international fusion research projects and DEMO.
- It is recommended that NIFS will deepen its collaboration with QST and overseas organizations so that the various knowledge, technologies, and outstanding human resources obtained in this study can be utilized in future fusion research.
- It is recommended that the DETS will contribute to tritium decommission of the LHD by their skill of radioactive treatment.
- Since the LHD project is approaching the completion, the DETS is encouraged to participate in planning of post-LHD projects and to acquire new technologies for them.
- Measures to strengthen cooperation between researchers and technical staff will be necessary after the reorganization (newly organized units and platforms) of NIFS. Reorganization of the DETS may be one of options.

Perspective 2

Has the DETS contributed to the maintenance and utilization of the research platform in NIFS ?

Findings/Evaluation

- NIFS has a total of 34 research platforms in addition to the LHD, including the supercomputer (RAIJIN) and engineering research facilities, and the DETS supplies technical cooperation and support for many of these platforms. Since the LHD is a large and central research platform at NIFS, considerable effort by the DETS has been focused on the maintenance, operation, and utilization of the LHD, which have made very high-level research possible in NIFS.
- The DETS have contributed to the operation and maintenance of many components of the LHD, such as the superconducting coils, vacuum vessel, vacuum exhaust system, exhaust gas treatment system etc. The DETS also greatly contributes to the maintenance of heating devices such as ECH, NBI, and ICH. In addition, the DETS has been involved in the machining of microwave transmission miter bends and ECE focus mirrors, electronic work for PN photodiode amplifiers, and repair of circuits that cannot be repaired by the manufacturer, and the fabrication of equivalent

products.

- The DETS manages the annual schedule including not only experiments but also machine inspections collaborated with the research department, which greatly contributes to the high availability of LHD operation.
- The DETS has also appropriately maintained and managed the research platform mainly used for reactor engineering research, including the high-current high-temperature superconducting conductor development system for fusion, the ultra-high heat load test system ACT, the transmission electron microscope (TEM), the ion beam analysis system, and the heat and mass flow loop system (Oroshi-2).
- The DETS also provides technical support through the Division of Information and Communication Systems, the Machinery and Circuit Engineering Department of the Fabrication Engineering Division, and the parts management system of the Central Parts Shop.
- The DETS also contributes to the other research platforms through a wide range of technical support, including the fabrication of apparatuses and electronic circuits required for experiments, development of control systems, network management, and web system development.
- Many complex systems/facilities were maintained by the limited resources with substantial efforts. All platforms have been operated well, especially for the LHD, which has a very high availability (92.1% since 2017) and reliability (nearly zero leakage in recent 10 years).
- From abovementioned findings, the activities of the DETS can be regarded as *Excellent*.

Recommendations

- Recently some small electrical and mechanical components can be quickly purchased from some vendors (e.g. MonotaRO). By considering this situation, it is recommended that the DETS needs to manage the Central Parts Shop more efficiently and effectively.
- The DETS should organize and disclose information on developed technologies so that the technologies developed in the maintenance of the NIFS research platform can be continuously used to promote future research activities.
- It is desirable that the platforms of the engineering research facilities will be prioritized to optimize the maintenance activities based on actual use results.
- Contribution to the Plasma Simulator is somewhat limited in comparison with the other activities and is expected to be enhanced in the future.
- The DETS should provide more information on engineering research facilities such as how they are served for inter-universities or international joint researches.
- For more efficient contribution of the DETS in line with the new paradigm of NIFS, it will be necessary to prioritize and optimize tasks and facilities.

Perspective 3

Are safety and health initiatives sufficient ?

Findings/Evaluation

- Three members from the DETS serve as the heads of the Safety and Health Promotion Department (Radiation Control Room, Machinery and Equipment Control Room, and Hazardous Materials

Control Room), and a total of 57 members of the DETS are working as members of the Safety and Health Promotion Department. These activities contribute to the promotion of safety and health in NIFS and can be *highly evaluated*. In particular, the Radiation Protection Office is staffed by about 16 Radiation Protection Office members from the DETS, who contribute greatly to the operation of the Radiation Protection Office.

- The DETS holds an annual "Information Exchange on Occupational Health and Safety Meeting", which is known to be a valuable opportunity for participants from universities and research institutes to exchange information. All technical staff belonging to the DETS are assigned to the self-defense fire brigade district team for the LHD, which responds in the event of a disaster related to the LHD. The DETS conducts fire drills twice a year before the start of the LHD experiments. The safety awareness among the technical staff has been demonstrated to be at a sufficiently high level.
- From abovementioned findings, the activities of the DETS can be regarded as *excellent*.

Recommendation

- Continuous efforts for safety and health in the DETS are important because radiation control must be carried out for a long period of time even after the LHD experiment is completed. It is necessary to establish a continuous safety management system, including the transfer of technology.

Perspective 4

As an Inter-University Research Institution, has the DETS conducted technical collaboration, exchange, and cooperation with universities and research institutes ?

Findings/Evaluation

- The DETS conducts technical exchanges with technical staff from universities and research institutes in accordance with the "Technical Exchange Program" for various technical themes, such as analysis technology using the finite element method ANSYS and NC machining technology.
- The DETS regularly organizes technical workshops as a forum for the technical exchange among technical staff nationwide. Furthermore, for the exchange of information among technical staff within the National Institutes of Natural Sciences (NINS), the NINS technical research meeting is held annually in rotation among the five institutes and the DETS organizes this meeting.
- The DETS provides a wide range of technical assistance to researchers, engineers, and students enrolled at universities, including mechanical fabrication, vacuum, and cryogenic-related technologies.
- The DETS contributes to the management and maintenance of rental equipment and is working to reduce operating costs by repairing equipment as much as possible on-site in the event of a breakdown during rental.
- The DETS has promoted international technical cooperation; international joint research with ITER in France and design support for CFQS in China. The DETS also provided a TESPEL injector to the Wendelstein 7-X device in Germany.
- The abovementioned technical exchanges can be *highly evaluated* because they have led to the improvement of technical skills not only of the staff of the DETS, but also of the technical staff belonging to outside universities and research institutes.
- From abovementioned findings, the activities of the DETS can be regarded as *Excellent*.

Recommendations

- It is recommended to build a new framework for the technical supports to universities and research institutes outside of the present joint research frameworks.
- The mission of NIFS as an Inter-University Research Institute is to contribute to strengthening the research capabilities of universities. The technical cooperation to universities and research institutes by the DETS, which has various technologies in the field of plasma and fusion, will become more and more important in the future. It is desirable that the DETS will strengthen its technical cooperation with universities and research institutes while taking care not to overload the technical staff.
- It is recommended that the DETS continues to host and manage technical exchange program to a broader range and to cover more institutions from abroad.
- Collaborations with international facilities are also highly recommended. New facilities under design/construction could be considered, such as STEP in UK, SPARC in USA.
- The present activities should be continued because it is important for the technical staff to improve and develop their skills.

Perspective 5

Has the DETS utilized its technical experience and knowledge accumulated so far, for industry-academia collaboration activities ?

Findings/Evaluation

- The DETS makes industry-academia collaboration by using their accumulated knowledges such as dissimilar metal bonding technique. The DETS also responds to requests for technical assistance from private sectors and obtained external funding for improving technical skills of technical staff.
- From abovementioned findings, the activities of the DETS can be regarded as *Commendable*.

Recommendations

- It is recommended that DETS increases their collaboration with industry more and enhances ripple effects of fusion engineering techniques to various other fields.
- It is recommended that through industry-academia collaborations and commissioned research with private sectors external funding is tried to be obtained for enhancing performance of academic and engineering activities in NIFS.
- In order to promote industry-academia collaboration, it is necessary for the executive management of NIFS to establish a mechanism to link the seeds possessed by the DETS with the needs of companies. On the other hand, it is necessary to clarify the scope of industry-academia collaboration so that the promotion of industry-academia collaboration does not affect the main work of NIFS, which should be performed by the DETS.
- It is recommended that a review system would be established to examine whether the collaboration activities are in line with the future development of NIFS.

Points of Evaluation 6

Is there an environment that supports the autonomy of individual technical staff members,

together with a systematic effort to improve and to pass on techniques ?

Findings/Evaluation

- In the past five years, about 11 technical staff members have retired and 10 new technical staff members have been hired, resulting in a turnover of about 1/5 of the technical staff. Appropriate training programs are provided for new technical staff, which is *highly evaluated*.
- By actively encouraging young technical staff to participate in technical training outside of NIFS including international joint research, opportunities are provided for young technical staff to introduce development of equipment and learn specialized skills, which is highly evaluated.
- One technical staff was selected for the "PM Development and Promotion Program" of JST. One ECRH technician in the DETS transferred to the ITER organization.
- There are some projects resulted from autonomy of young technical staffs, which can be further encouraged in accordance with their daily duties.
- From abovementioned findings, the activities of the DETS can be regarded as *Excellent*.

Recommendations

- For future career path of staff members, it is recommended to promote collaborations and personnel exchange between different groups.
- In order to systematically work on the inheritance, development, and improvement of technology in the DETS, it is necessary to work out plans as soon as practicable for a post-LHD project and research platform of NIFS, and to clarify the technology required for the future of NIFS.
- NIFS will enter the post LHD era from the next fiscal year. With a view to the future development for the next-generation fusion experimental devices, the necessary technologies should be identified, improved, and passed on, based on discussion not only within the DETS but also the entire NIFS.
- It is recommended that the DETS will find more collaborating opportunities with international programs, especially ITER. This could bring the DETS more international reputation and potential resource.
- The DETS is encouraged to continue to work toward obtaining external funds to the extent that it does not lead to excessive workloads for the technical staff.

General Recommendations and Comments

- It is not easy to estimate the contribution of the DETS alone to the NIFS activities, especially the safety and health initiatives/ the cooperation with universities and research institutes, because they are established by the integration works of the NIFS organization. It is recommended that these items of the safety and health initiatives/ the cooperation may be estimated as a whole of NIFS, not the DETS in next time.
- At the completion of deuterium experiment on the LHD, the roles of DETS at NIFS needs to be carefully considered in accordance with the reorganization of research projects into “units”. It will be expected that the DETS can support the research activities of “units”, whereas each of the research theme would be smaller than before (in budget and human resources). Therefore, more tight collaborations and discussions with the research staffs in “units” are highly encouraged along with inter-university collaborations with research and education at universities.

Annex

List of FY2022 NIFS External Peer Review Committee members

[External Peer Review Committee members]

	Ikeda Yoshitaka	Managing Director, Fusion Energy Directorate, National Institutes for Quantum Science and Technology (QST)
●	Ueda Yoshio	Professor, Graduate School of Engineering, Osaka University
	Ohno Noriyasu	Professor, Graduate School of Engineering, Nagoya University
	Ozawa Tohru	Professor, Faculty of Science and Engineering, School of Advanced Science and Engineering, Waseda University
	Kaneko Toshiro	Professor, Graduate School of Engineering, Tohoku University
●	Kishimoto Yasuaki	Specially Appointed Professor, Institute of Advanced Energy, Kyoto University
	Fujisawa Akihide	Professor, Research Institute for Applied Mechanics, Kyushu University
	Matsuoka Ayako	Professor, Graduate School of Science, Kyoto University
◎	Yamada Hiroshi	Professor, Graduate School of Frontier Sciences, The University of Tokyo
○	Yoneda Hitoki	Professor, Institute for Laser Science, University of Electro-Communications
	Watanabe Tomohiko	Professor, Graduate School of Science, Nagoya University
	Stewart Prager	Professor, Astrophysical Sciences, Princeton University, USA
	Philip J Morrison	Professor, Department of Physics, The University of Texas at Austin, USA
	Yuntao Song	Director-General, Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

[Specialist Committee members]

Iso Satoshi	Professor, Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK)
Motohara Kentaro	Director of Research Coordination & Professor, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences(NINS)
Kimura Yoshifumi	Professor, Graduate School of Mathematics, Nagoya University
Shigemasa Eiji	Technical and Engineering Department Head of Department, Institute for Molecular Science (IMS), National Institutes of Natural Sciences(NINS)
Uzawa Yoshinori	Director of Engineering & Professor, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences,(NINS)
Motomiya Kenichi	Job Group Representative, Safety and Maintenance Management Group , Organization for Academic Activity Support Division of Engineering and Technical Staff, Tohoku University
Hantao Ji	Professor, Astrophysical Sciences, Princeton University, USA

◎: Chairperson, ○: Vice Chairperson, ●: Expert Subcommittee's Chairperson

List of FY2022 NIFS External Peer Review Committee members
Expert Subcommittee on Human Resource Development and International Cooperation

[External Peer Review Committee members]

●	Kishimoto Yasuaki	Specially Appointed Professor, Institute of Advanced Energy, Kyoto University
	Ozawa Tohru	Professor, Faculty of Science and Engineering, School of Advanced Science and Engineering, Waseda University
	Kaneko Toshiro	Professor, Graduate School of Engineering, Tohoku University
	Fujisawa Akihide	Professor, Research Institute for Applied Mechanics, Kyushu University
	Matsuoka Ayako	Professor, Graduate School of Science, Kyoto University
	Stewart Prager	Professor, Astrophysical Sciences, Princeton University, USA
	Philip J Morrison	Professor, Department of Physics, The University of Texas at Austin, USA

[Specialist Committee members]

Iso Satoshi	Professor, Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK)
Motohara Kentaro	Director of Research Coordination & Professor, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences(NINS)
Kimura Yoshifumi	Professor, Graduate School of Mathematics, Nagoya University
Hantao Ji	Professor, Astrophysical Sciences, Princeton University, USA

●: Expert Subcommittee's Chairperson

List of FY2022 NIFS External Peer Review Committee members
Expert Subcommittee on the Department of Engineering and Technical Services

[External Peer Review Committee members]

●	Ueda Yoshio	Professor, Graduate School of Engineering, Osaka University
	Ikeda Yoshitaka	Managing Director, Fusion Energy Directorate, National Institutes for Quantum Science and Technology (QST)
	Ohno Noriyasu	Professor, Graduate School of Engineering, Nagoya University
	Watanabe Tomohiko	Professor, Graduate School of Science, Nagoya University
	Yuntao Song	Director-General, Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

[Specialist Committee members]

Shigemasa Eiji	Technical and Engineering Department Head of Department, Institute for Molecular Science (IMS), National Institutes of Natural Sciences(NINS)
Uzawa Yoshinori	Director of Engineering & Professor, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences,(NINS)
Motomiya Kenichi	Job Group Representative, Safety and Maintenance Management Group , Organization for Academic Activity Support Division of Engineering and Technical Staff, Tohoku University

●: Expert Subcommittee's Chairperson

Annex 2: Backgrounds

The National Institute for Fusion Science (below as NIFS) was established in 1989 as an inter-university research institute to advance fusion research in universities in Japan.

Since 2004, NIFS has been a research institute under the Inter-University Research Institute Corporation National Institutes of Natural Sciences for enhancing further the domestic research collaboration. Upon becoming an inter-university research corporation, a system for mid-term goals and mid-term planning spanning six years was introduced, and a system of annual evaluations regarding the progress, too, was introduced. This annual evaluation focuses primarily upon administrative management. However, at NIFS it has been determined that receiving external evaluations of research results is important. Under the NIFS Advisory Committee, each year an External Peer Review Committee is organized, and the members evaluate the research. The topics of evaluation are determined by the Advisory Committee. The evaluation is undertaken by the members of the External Peer Review Committee, which is composed of experts who are external members of the Advisory Committee and external experts who are appropriate for evaluating the topics. The External Evaluation Committee submits its evaluation results to the Advisory Committee. Then, NIFS, together with making the results public by uploading that information to the NIFS homepage, utilizes this information to improve research activities in the following years.

The topics for evaluation for the External Peer Review Committee are discussed and decided upon by the Advisory Committee, and those topics for evaluation differ each year. Most recently, in 2018 the LHD Project, in 2019 the Numerical Simulation Reactor Research Project, in 2020 the "Division of Health and Safety Promotion", the "Division of Information and Communication Systems", and the "Division of External Affairs", and in 2021 the "LHD Project", the "Numerical Simulation Reactor Research Project", and the "Fusion Engineering Research Project" were topics evaluated by external reviewers. This year, 2022 "Human Resource Development" ,"International Collaboration", and the "Department of Engineering and Technical Services" were selected and reviewed by the external examiners.

As external members of the External Peer Review Committee this year there are eleven external members from the Advisory Committee and three members from abroad. Further, seven(including a member from abroad) experts are invited from outside NIFS. Thus is the External Peer Review Committee composed, and thereby the evaluation was undertaken.

The first meeting of the External Peer Review Committee including the Experts' Subcommittee was convened on October 11, 2022. The Committee discussed the process for moving forward with this fiscal year's external peer review. The second meeting of Experts' Subcommittee on the "Department of Engineering and Technical Services" was held on November 7, 2022. The second meeting of Experts' Subcommittee on the "Human Resource Development and International Collaboration" was held on November 15, 2022. NIFS provided a detailed explanation that utilized documents from the material of viewgraphs and reports based on the perspectives. A question-and-

answer session also was arranged. Extra-meetings primarily for international members were organized for “Department of Engineering and Technical Services” on November 29, 2022, and “Human Resource Development and International Collaboration” on December 8, 2022 with participation of major members in Japan. Subsequently, the second meeting of the External Peer Review Committee and the third meeting of the Experts’ Subcommittee was held on January 30, 2023. The Committee discussed the coordination of the evaluation work and confirmed the configuration of the external peer review report based on the drafts from two sub-committees. Then, the committee elaborated the report through communications by electronic mail. Upon confirmation and examination by the External Peer Review Committee and the Experts’ Subcommittee, the external review report was finalized on March 6, 2023.

In the external evaluation regarding NIFS’s “Human Resource Development”, “International Collaboration”, and the “Department of Engineering and Technical Services” which were implemented this fiscal year, the perspectives for the evaluation were determined as follows.

Evaluation items in FY2022 External Peer Review

The external evaluation of "Human Resource Development (HRD)", "International Cooperation (IC)", and the "Department of Engineering and Technical Services (DETS)" in FY2022 was conducted with evaluation perspectives set as follows. Each perspective is essentially based on the evaluation of the appropriateness and achievement of research and other activities conducted by the National Institute for Fusion Science (NIFS) as an Inter-University Research Institute, as well as future direction and strategy, referring to the "Proposal for the Future of NIFS" compiled in FY2021.

In addition, the following points presented as "recommendations" in previous peer review reports of the "Current 3 Projects" in FY2021 and the "DETS" in FY 2006, are also taken into consideration in this evaluation.

Recommendation for "Current 3 Projects" in FY2021

(1) The committee notes that the activities of postdocs do not reach a commendable level. The number of JSPS research fellows (PD levels) has been zero in the last few years. These facts show that NIFS has failed to provide attractive career paths to young scientists, compared with well-known scientific institutes overseas. To maintain the high-level standards and the vitality of the institute in the plasma-fusion research field, it is essential to keep a constant entry of new talented researchers into the community. The committee recommends that NIFS should take measures to improve the situation.

(2) It is commendable that NIFS has proceeded with research projects under agreements with 33

institutes in 15 countries. International collaborations were promoted either under many bilateral or under multilateral frameworks. The committee recommends that NIFS should assess the effectiveness of each agreement and should better selectively activate the substantial number of exchanges of researchers and collaboration research, based on the assessment.

Recommendation for "DETS" in FY 2006

(1) The scope of the DETS has been expanding, according to a variety of experiments, digitization in the research environment due to the progress of research, social demand and its variants. On the other hand, difficulty in passing knowledge and techniques on to the younger generation has emerged, due to the retirement of skilled staff. Although it is determined, at present, that they can handle a wide range of tasks related to the LHD with organizational and individual efforts, it is necessary to take measure to manage personnel in the near future.

(2) The Technical Subcommittee points out the existence and necessity of fundamental techniques that require time to develop and pass on, such as advanced technologies, special and skilled techniques, and know-how. The subcommittee also demands or recommends that staffing be optimized and realized with a long-term vision, according to the overall policies and plans of NIFS.

Perspectives on "HRD"

(1) Through graduate school education in Sokendai and cooperative universities, has NIFS fostered scientists and engineers who will lead fusion research and development?

(2) Has NIFS advanced human resource development for young people in Japan and abroad, not only in the narrow sense of fusion science, but also in terms of interdisciplinarity and its exchange?

(3) Are there any efforts to support young researchers, including those of post-doctoral fellows and assistant professors, in starting and developing their research?

(4) Has NIFS provided a world-class research environment where young researchers can take the first step in their career path after obtaining a Ph.D., and where students who aspire to become researchers can be nurtured?

Perspectives on "IC"

(1) Has NIFS taken the initiative in international research activities?

(2) Has NIFS been able to promote systematic academic exchanges with highly competitive foreign research institutions, and continuing world-class collaborative work among researchers as a result of such exchanges

(3) Is NIFS contributing to ITER and BA activities?

(4) Is NIFS promoting international joint research using research platforms?

(5) Has a system been established to facilitate international joint research?

Perspectives on "DETS"

(1) Has the DETS contributed to the preparation and implementation of the deuterium experiment (plasma performance improvement) in the LHD?

(2) Has the DETS contributed to the maintenance and utilization of the research platform in NIFS?

(3) Are safety and health initiatives sufficient?

(4) As an Inter-University Research Institution, has the DETS conducted technical collaboration, exchange, and cooperation with universities and research institutes?

(5) Has the DETS utilized its technical experience and knowledge accumulated so far, for industry-academia collaboration activities?

(6) Is there an environment that supports the autonomy of individual technical staff members, together with a systematic effort to improve and to pass on techniques?

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