Preface

Since its foundation in 1925 in the aftermath of the Great Kanto Earthquake, the mission of Earthquake Research Institute (ERI) has been to promote research on earthquakes and volcanic eruptions and to develop methods for mitigating related disasters. We have been working in cooperation with national universities in Japan since 1994 as a Shared-Use Institution. ERI were designated as a Joint Usage/Research Center for Japanese universities in 2010 and has been promoting multi-disciplinary research in the field of solid earth science for many years, in collaboration with a wide range of Japanese universities and research institutes.

ERI was conducted three external reviews since its reorganization to a Shared-Use Institution in 1994. After the third external review, a subsequent reorganization took place in 2010 so that it could serve as a Joint Usage/Research Center for Japanese universities. The first external review was conducted by a committee consisting of seven Japanese and five foreign researchers in 1999. Their report, issued in 2000, evaluated the validity of ERI's scientific objectives (e.g., ocean hemisphere research plan), the involvement of our faculty members in the education of graduate students at the University of Tokyo, and our invitation of foreign researchers, and rated them all highly. The report called for a functional strengthening of our outreach activity and planning committee of Earthquake Prediction Research Program, in connection with our function as a Shared-Use Institution for national universities. In 2003, the second external review was conducted as a follow up to the first external review, involving the same Japanese committee members who participated in the first external review. The report confirmed the progress of reforms made in response to the recommendations of the first external review, and noted that additional time was needed to achieve the desired outcomes for some items. After the second external review, national universities transitioned to corporations and the circumstances of the university and the research institute changed dramatically. The flexible management of budget implementation was guaranteed, however the total budget gradually decreased in the name of improving efficiency. The University's governance by its president and board of directors was strengthened. On the other hand, we are requested to get result within a short time according to mid-term plan. The research environment of ERI improved physically thanks to the construction of our first seismically isolated building in 2006. ERI then compiled a future plan for operating as a Joint Usage/Research Center, which included formulating a new scientific plan and a reorganization plan, based on the previous external review results and the discussions of our planning committee. The third external review was conducted in 2009, and

the validity of our scientific plan was confirmed. On the other hand, some concrete recommendations related to management, human resources development and education, outreach, and international activities were proposed, and the changes made in response to these recommendations are reflected in our current management system.

Circumstances have changed during the five years since the confirmation of our scientific plan and our reorganization in 2010. Some of these changes were the result of The 2011 off the Pacific coast of Tohoku Earthquake, which was the largest earthquake ever recorded in Japan, as well as the establishment of two new research centers. We discussed on possible revisions to the scientific plan. A fourth external review was conducted in June of 2014 in order to evaluate the results of the scientific plan adopted in 2010, to consider revision of the scientific plan, and to assess the two recently established research centers. It is our understanding that the report which will be issued as a result of this fourth external review will positively evaluate the proposed revision of our scientific plan, our management and our future plans for the new research centers. ERI has also received many constructive, multi-disciplinary recommendations on the implementation of our scientific plan, and we would like to express our intention to respond positively to the evaluations and recommendations issued by this external review committee, as we have responded to previous external reviews, and to confirm that the committee's findings will be reflected in the future management of the institute.

In conclusion, we would like to express our deepest gratitude to Prof. Kiyoshi Suyehiro, the chairperson of the external review committee, and to the eight domestic and foreign committee members who agreed to serve on this committee, for their attendance at three days of committee discussions, for their pre-evaluation of documents distributed in advance, and for the summarization of their report based on their post-evaluation findings.

September, 2014

Takehiro Koyaguchi
Director, Earthquake Research Institute, The University of Tokyo

Table of Contents

EXTERNAL REVIEW REPORT
FOR EARTHQUAKE RESEARCH INSTITUTE OF THE UNIVERSITY OF TOKYO
September 2014

1. Introduction

This report describes the external review of the University of Tokyo, Earthquake Research Institute (hereafter ERI) conducted in 2014. This external review of ERI was the fourth such activity to review the activities in the light of the science plans drafted by ERI:

2000: First External Review (Decadal Future Plan 1999 (FP99))
2003-4: Second External Review (Interim progress of FP99)
2009: Third External Review (Decadal Future Plan 2009 (SP2009))
2014: Fourth External Review (SP2009 and SP2009 Addendum)

2. External Review

2-1 Mandate

The external review committee was requested to review and make recommendations on the following items with priority on the first four items:

(1) Research performance along the science plan established in 2009
(2) Addenda to the science plan 2009
(3) Administration of the Center for High Energy Geophysics Research – Present and Future
(4) Management and future plans for the Research Center of Large-scale earthquake, Tsunami and Disaster
(5) Management of ERI
(6) Performance as Joint Usage/Research Center
(7) Human resources and education
(8) International and outreach activities.

2-2 Members of the External Review Committee (ERC)

Kiyoshi Suyehiro (Chair)
Principal Scientist
Japan Agency for Marine-Earth Science and Technology

Katharine Cashman
Professor, Department of Geological Sciences,

University of Oregon, USA

Donald Forsyth
Professor, Department of Geological Sciences,
Brown University, USA

Atsushi Iizuka
Director and Professor, Research Center for Urban Safety and Security
Kobe University

Kuo-Fong Ma
Professor, Department of Earth Sciences,
National Central University, Taiwan

Toru Matsuzawa
Director and Professor, Research Center for Prediction of Earthquakes and Volcanic Eruptions
Tohoku University

Paolo Emilio Strolin
Professor Emeritus, Università di Napoli Federico II, Italy
Istituto Nazionale di Fisica Nucleare (INFN), Italy

Mitsuhiro Toriumi
Director, Laboratory of Ocean-Earth Life Evolution Research
Japan Agency for Marine-Earth Science and Technology

2-3 Schedule of External Review Committee (ERC)

November 2013	Appointment of External Committee Members
May to June 2013	Preliminary review based on reports
June 10 to 12, 2014	ERC at ERI
June 10 (Tue)	
13:30~17:00	First ERC Meeting
	(English/Japanese with simultaneous interpretation)
	Introduction of ERC members
	Overview of ERI (Takehiro Koyaguchi, Director)

Explanation of the external review (Takehiro Koyaguchi, Kazushige Obara)

Discussion of preliminary review results (**only ERC**)

18:00~20:00 Reception (Forest Hongo)

June 11 (Wed)

09:00~12:00 Presentation of Science Plan (SP) and Results (English)

Overview of SP2009R and addenda from SP2009 (Takehiro Koyaguchi)

Comprehensive understanding of earthquake phenomena and advancement of earthquake forecasting (Hiroshi Satow)

Comprehensive elucidation of volcanic eruption and eruption prediction (Minoru Takeo)

Understanding Earth's internal activities through a multifaceted and integrated approach (Hisayoshi Shimizu)

Development of innovative observational technologies (Masanao Shinohara)

New development of disaster prediction science, as a comprehensive science (Muneo Hori)

Center for High Energy Geophysics Research (Hiroyuki Tanaka)

Research Center of Large-scale Earthquake, Tsunami and Disaster (Muneo Hori)

13:00~14:20 Laboratory tour

Center for High Energy Geophysics Research

Research Center of Large-scale Earthquake, Tsunami and Disaster

Ocean bottom observation

14:20~17:00 Presentation on managements and Discussion

(in Japanese with simultaneous interpretation)

Management (Takehiro Koyaguchi)

Joint usage/research center, nation-wide collaboration research plan (Naoyuki Kato)

Human resources and education (Hisashi Utada)

International and Outreach Activities (Kazushige Obara)

Discussion

17:00~19:00 Discussion with early career researchers including poster session (English)

(Participants: Hiroe Miyake, Takuto Maeda, Yujiro Suzuki, Fukashi Maeno, Akimichi Takeda, and Wijerathne Maddegedara Lalith Lakshman)

June 12 (Thu) Final ERC Meeting

(in English/Japanese with simultaneous interpretation)

09:00~16:00 Meeting of ERC members

16:00~17:00 Report to ERI Director (ERC Chair)

June to September 2014 Drafting of Report

September 2014 Submission of the Final Report of ERC

3. Summary of Recommendations

In this section, we summarize our recommendations based on our evaluations of ERI activities and achievements as presented to the ERC and are listed in the order of mandated evaluation items. The ERC reviewed the first four items with higher degree of attention. After the ERC meeting at ERI, the ERC members shared the view that the overall performance of ERI achieved along the direction described in SP2009 and SP2009R is high amongst world-class research institutions in geosciences. We encourage ERI to take larger strides in this direction into the future.

(1) Research performance along the science plan established in 2009

As stated above, we were generally impressed and satisfied by the achievements made along all five pillars. We recognize the multi-faceted directions of ERI: (a) holding a mission of significant societal relevance, (b) operating as a basic research institute, (c) encompassing large fields of science and engineering related to earthquakes and volcanic eruptions, (d) utilizing theories, modeling, developing new technologies, and experimenting in labs and fields. These are clearly strength for a research institution. We recommend that ERI actively work together to maintain and further this strength in an effective manner.

Specific comments are given in the following section according to the five pillars of the SP2009.

(2) Addenda to the science plan 2009

The 2011 Tohoku Earthquake and Tsunami Disaster[1] was the impetus for drafting SP2009R. SP2009R was drafted to address the challenge of infrequent (such as considering

[1] 2011 Earthquake off the Pacific coast of Tohoku (Great East Japan Earthquake) Mw 9.0 occurred on March 11 14:46 (JST), 2011. More than 18,500 perished and caused ~165BUSD damage.

millennium time interval) but massive natural disasters and emphasizes the need for interdisciplinary and international approach. We support the direction of SP2009R and in order to achieve the goals, we recommend that ERI draft an implementation plan based on SP2009 and SP2009R.

(3) Administration of the CHEER – Present and Future

We enthusiastically endorse the direction of CHEER in muography accompanied with further R&D utilizing scintillation and nuclear emulsion technologies. We strongly recommend ERI to find ways to renew the term of CHEER so that CHEER can play a key role in international collaborations, which we encourage in order to effectively face the challenges in the field of research. We also recommend timely reviews to be made for the effectiveness of the science utilizing elementary particles.

(4) Management and future plans for the Research Center of LsETD

The hard lesson from the 2011 Tohoku Earthquake prompted the establishment of the Center. We endorse the approach to integrate earth science and earthquake engineering to be realized by this Center. In order that the Center may play a dominant role in disaster prevention and mitigation, we recommend that every effort will be made by ERI to keep the computing capabilities of this Center at the cutting edge.

(5) Management of ERI

We recognize that ERI is managed within various boundary conditions imposed externally as with all other research institutions. On this aspect, we suggest that ERI Director take efforts through his/(her) leadership in turning external threats to opportunities such as by promoting trans-disciplinary or novel fields for better chance of attracting funds and new hires towards the goals of SP2009 and SP2009R.

(6) Performance as Joint Usage/Research Center[2]

ERI has been designated as the only "Joint Usage/Research Center for Earthquake and

[2] JU/RC for universities: ERI is designated by MEXT as one of the centers with official mechanism to provide research facilities to (joint usage) and to conduct joint research projects with researchers nationwide.

Volcano Science" in Japan since 2010. While the performance has been very high, we are aware that such achievement has been made based on the unselfish dedication of the staff at ERI supporting the JU/RC. As the new 5-year national program "Promoting the Earthquake and Volcano Hazards Observation and Research Program" started in 2014 after the hard lesson of the 2011 Tohoku Earthquake, we recommend that ERI oversee the promotion of the program in a healthy academic environment.

(7) Human Resources and Education

We encourage the continuing efforts being made by the DEP office (Developing human resources and Education Promotion). We were somewhat disappointed to observe that significant improvements in gender balance or non-Japanese staff hiring were not apparent. We recommend efforts in this direction as well as in the recruitment of more Ph. D. students.

(8) International and Outreach Activities

The Outreach Office of ERI is performing actively through various channels from printouts to web-based media to the public and policy makers. We recommend the continuation of these efforts.

We endorse the activities by the International Office for the promotion of international research on earthquakes and volcanoes. We note that the SP2009R emphasizes the importance of international participation and recommends that the International Office seize on this opportunity.

4. Evaluations and Recommendations

The Science Plan of the Earthquake Research Institute (ERI) forms the basis and guiding document for the research activities at ERI. The Science Plan that applies to the decade starting from April 2009 is called SP2009. In March 2011, the 2011 Tohoku Earthquake and Tsunami caused devastating disaster in modern Japan since the 1923 Kanto Earthquake and the 1995 Kobe Earthquake, which led to various checks and reviews at the national level looking into all aspects of the disaster including the role of the relevant science communities. The ERI conducted its own review and augmented the SP2009 to formulate a revised Science Plan (SP2009R). This external review exercise took place halfway through the decadal period, because of ERI's renewed determination to respond to this grave incident.

The 2011 Tohoku Disaster challenged the researchers to assess ways in which science and

technology may provide useful solutions to the risks imposed on Japan. Specifically, understanding infrequent and massive natural disasters suddenly called for major attention. The SP2009R addresses these points by emphasizing the direction to develop innovative, international/interdisciplinary observational technology and to introduce cutting-edge computing science. The SP2009R emphasizes the importance of building a group of hierarchical numerical models ("community model") through integration of dispersed and individualistic observations that connect to disaster predictions, and by combining observations and simulations to cope with the disasters underpinned by solid basic science.

We note that although all discussions and the contents of this report were shared among all the External Review Committee members, the specific topics of (1) the management of ERI and (2) the role of ERI in joint usage/research with other Japanese research institutes were reviewed only by the Japanese committee members, as requested.

(1) Research performance along the science plan established in 2009

SP2009 stipulates five key pillars to be the priority research fields of ERI:

Pillar 1: Comprehensive understanding of earthquake phenomena and advancement of earthquake forecasting,

Pillar 2: Comprehensive elucidation of volcanic eruption and eruption prediction

Pillar 3: Understanding Earth's internal activities through a multifaceted and integrated approach,

Pillar 4: Development of innovative observational technologies,

Pillar 5: New development of disaster prevention science, as a comprehensive science.

Scientists and engineers at ERI are not compartmentalized into each Pillar. They collectively conduct research through three main categories: (1) basic research, (2) mission oriented research, and (3) joint research with other universities and research institutions in Japan. There are 4 research divisions aimed mainly at conducting basic research, and 5 research centers with defined missions. There are 3 Science Management Centers for providing planning, observational facilities, and data management that crosscut all disciplines and intramural and extramural activities. Each of the 12 organizational units (divisions and centers) except the Research Center for Large-Scale Earthquakes, Tsunami and Disaster, which is solely designed to contribute to Pillar 5, has multiple objectives in more than one Pillar.

The following comments include the addendum of SP2009R in their evaluations. Note also

that these comments are not made for each organizational unit, therefore there are cases where the same unit name appears in different Pillars. However, in our review process, we first went through the activities of each unit. We reorganized our comments to be in line with the SP2009 and SP2009R as requested after discussion and debates within the committee members and are presented below.

Pillar 1: Comprehensive understanding of earthquake phenomena and advancement of earthquake forecasting

1. ERI has done an excellent job over the years on the theme of comprehensive understanding of earthquake phenomena. The efficient transfer of domestic and global observational data obtained from the 2011 Tohoku earthquake to scientific results is impressive. It is a tremendous contribution to the earthquake community worldwide given the rarity of the event and its fault zone within proximity of world's most dense geophysical networks. ERI proved its world leadership in earthquake study. We strongly recommend ERI continue to promote the plan under this merit and also encourage their advancement effort in earthquake forecasting on physical grounds.
2. We recognize the tremendous data in volume and quality associated with the 2011 Tohoku earthquake process resulted from the great foresight more than 50 years ago by Japanese seismologists and continuing efforts to advance and expand the capabilities of earthquake monitoring inland and offshore. The high quality of the data owes also to modern innovation in observational technologies. Furthermore, the open-data policy made the unprecedented data quality and quantity to be exploited by the Japanese scientists and also by the international researchers. This cannot be overemphasized as these data lead to the break-through findings on the understanding of rupture process of the mega-thrust earthquake as well as the processes leading to and following after the event.
3. Truly large events often tragically bring devastating disasters as such as the 2004 Sumatra and 2011 Tohoku earthquakes. Such huge societal relevance requires scientists' best efforts to understand the mega-thrust event when such rare events occur. What controls the occurrence and slip of the subduction zone events? How does an earthquake cycle work? What controls fault zone dynamics? In particular, related to all these questions, a fundamental question is raised on the role of fluid in the fault zone. We encourage continued effort on collaborative and multi-disciplinary work on understanding the dynamics of fault zone and subduction zone systems combining

theoretical, experimental to observation and modeling studies, for which ERI has strengths in all aspects.

4. ERI has shown their excellent capability in modeling and prediction of ground motion for disaster mitigation. Such results should prove to be of practical use for early warnings. We note, however, that the size and the extent of the 2011 Tohoku earthquake causing the tsunami that brought the calamity were not predicted let alone its imminence. As the theoretical geoscience on friction law and dynamic modeling on stress and strain conditions in the brittle crust and the ductile crust/mantle has advanced with verifications by the real data, we anticipate that it will lead to advances in research on physics-based earthquake prediction.

Pillar 2: Comprehensive elucidation of volcanic eruption and eruption prediction

1. Overall, the volcano group is very strong, and encompasses everything from detailed studies of active and recently active volcanoes, to creative development of observational and monitoring tools, to developing complex models of volcanic processes. The large number of active volcanoes in Japan makes it an ideal natural laboratory, and the group, as a whole, has been taking advantage of this opportunity.

2. The larger goals of understanding deep processes of magma accumulation and the dynamics of volcanic conduits are admirable, but these are major challenges in the volcanology community as a whole, and will require developing new ways to monitor subsurface processes in addition to better experimental and theoretical understanding of the rheology of complex materials. In this regard, we note that there appears to be a mismatch between the desire of the volcano group to incorporate materials science, and the focus of the materials science group on the rheology of mantle materials. Geophysics appears to be better integrated into these goals, particularly with regard to cutting edge research in high precision gravity measurements and muography. Together, gravity, muography and deformation have the potential to provide exciting insight into shallow conduit processes, particularly if all data can be obtained in near-real-time. A challenge is how to extend these data to monitor deeper processes.

3. We would have liked to see more discussion of plans to improve both long-term forecasting and short-term predictions of eruptive activity. For example, there is mention in 2.10.5 of “eruption scenarios” that have been developed for specific recently active volcanoes (Miyakeshima, Sakurajima, Kirishima and Usu); in light of SP2009R, however,

it seems important to consider scenarios for "maximum probable" eruptions as well. Another challenge (from an international perspective) is to effectively integrate real-time monitoring observations into probabilistic event-tree models for eruptive activity.

4. We noted that the matrix showing the intersection of the 5 pillars with the Divisions and Centers within ERI does not show a role for disaster mitigation science within the volcano program. Additionally, although renamed as EVIC (Earthquake and Volcano Information Center), to date the center focuses exclusively on earthquakes and tsunamis. This is understandable given not only the history of disaster research and information in Japan, but also the impact of the 2011 earthquake on disaster science. We note, however, that many of the same needs identified for earthquakes (databases, real-time information, studies of high magnitude events, studies of past events, international collaborations) also apply to volcanology. Some of these topics are mentioned in Sec 2.10.5 (CCEVPR), so perhaps this apparent lack of coordination is simply a function of the distribution of responsibilities between the different science management centers.

5. Another opportunity identified in SP2009R is to address the effect of crustal stresses on volcanic activity. This is an important challenge in volcanology in general, and the nature of ERI makes it an ideal place to develop comprehensive models of crustal processes that relate seismic and volcanic activity. From the perspective of volcanology, elucidating links between crustal stress/strain and magma migration and accumulation would be exciting, and could be a way to make progress in the area of recognizing when magma systems are approaching a critical threshold for the onset of eruptive activity.

6. The dual focus of ERI on both volcanic and seismic hazards also creates an opportunity to combine aspects of hazard and risk assessment from both communities, and thereby develop new and innovative approaches to both hazard prediction and mitigation.

7. Finally, the bottom-up structure of ERI research is working well in terms of generating world-class basic research. We note, however, that making progress on the larger goals identified in SP2009 and SP2009R may require new strategies for integrating studies of individual volcanoes and volcanic processes into general models for magmatic systems.

Pillar 3: Understanding Earth's internal activities

1. Overall, this pillar of research at ERI is world-class, leading in observations, some areas of material research, and the development of innovative technologies to advance the observations. It is making excellent progress in fulfilling the 2009 Science Plan.

2. Plate tectonics and convection in the interior of the Earth are ultimately responsible for earthquakes and volcanic eruptions. The manifestations of this activity in the interior of the Earth are modified by the effects of fluids, particularly in subduction zones. Thus a comprehensive understanding of earthquake phenomena and volcanic eruptions requires study of material circulation in the Earth's interior on a wide range of scales, ranging up to the globe as a whole. Progress in this pillar of the 2009 Science plan is centered on new observations of structure and new observational technologies, but these can never be complete in themselves; they must be interpreted in the light of theoretical and numerical models. Linking the observations and models must be an understanding of the physics involved, particularly the rheology describing the response of the Earth on small-scales to driving stresses. ERI is a strong contributor in all of these areas, and particularly is a world leader in observations in the oceans and observations of fault related structure on land.

3. The Ocean Hemisphere Research Center (OHRC) is a highly productive and innovative group that concentrates on plate tectonic processes, large-scale structure of the mantle and core, and convection in the interior of the Earth. Seismological and electromagnetic measurements are the most prominent observations, although heat flow also plays an important role. The OHRC group has made a number of important discoveries that affect our understanding of how plate tectonics works in the oceans. Some of these observations are surprising, forcing rethinking of our classical, simple plate tectonic models and pointing out the importance of a continued program of new observations with new tools and higher resolution. The NoMAN (Normal Oceanic Mantle) project studying the lithosphere and asthenosphere structure in the western Pacific is an excellent example of using state-of-the-art instrumentation in an innovative approach; it should be continued and, in collaboration with international partners, expanded to address the 200 m.y. history of the Pacific.

4. The Center for Geophysical Observation and Instrumentation group has made strong contributions in developing ocean bottom instrumentation for both seismology and electromagnetic studies. The broadband BBOBS-NX instruments, for example, are the only instruments that are currently employed that largely bury the sensors, which is important for reducing noise on the horizontal components. Work is underway to make these self-recovering and include tilt measurements. The NUDOBS is the only long-term ocean bottom seismometer capable of operating at depths greater than 6500 m. The

long cable in the EFOS instrument allows electric field measurements to much longer periods with good signal-to-noise ratio. ERI is clearly a global leader in ocean-bottom instrumentation and interpretation of seismic and electromagnetic observations.

5. On land and off-shore, the efforts at mapping the structure of the earth associated with faults and the subduction zone through seismic tomography, active seismic reflection profiling, and electrical resistivity studies are unmatched anywhere in the world. Innovative techniques are being employed, such as improvements in resistivity modeling, using repeat earthquakes to monitor slip rates, and continuous monitoring of vertical displacements using seafloor pressure records, to cite just three examples. The MeSO-net project has contributed significantly to the evaluation of seismic hazards in the Tokyo area and the follow-up project on Reducing Vulnerability in Urban Mega Earthquake Disasters directly addresses goals of the revision to SP2009.

6. On a global scale, the geo-neutrino effort of the Center for High-Energy Geophysics Research is an interesting, new approach. Although it remains to be seen whether adequate resolution can be achieved, these observations have the potential to be one of the few ways to test models of the composition of the lower mantle of the Earth. Muography appears to be a useful addition to gravity measurements for shallow density determinations. Progress is clearly being made with both muons and neutrinos; the group is actively publishing, but a few more years of effort is probably needed to assess how practical these completely new approaches are for revealing more about how the Earth works.

7. Also contributing to global understanding of tectonics and convection are the international collaborative projects of both the Earthquake Prediction Research Center and OHRC studying plate boundaries around the world. Going forward, efforts of this type in subduction zones will be important for a goal outlined in the SP2009R Addenda in response to the 2011 Tohoku earthquake; i.e., comparing the characteristics of subduction zones that produce M 9.0 earthquakes. Focused efforts in this direction should be encouraged, although clearly external funding and collaboration is required.

8. Progress towards modeling large-scale behavior of the earth includes developing theory for computing viscoelastic deformation of a spherical earth with 3D variations in viscosity, work done within the Division of Monitoring Geoscience. On a much smaller scale, but necessary for incorporating physics in modeling and in the interpretation of

seismic and resistivity anomalies, the Division of Earth and Planetary Materials science is a global leader in understanding attenuation, the behavior of two-phase aggregates and the development of microstructures and anisotropy during deformation.

9. There has been progress towards modeling mantle flow in the Division of Theoretical Geoscience, most notably in representing the effects of small-scale convection in the mantle wedge above the subducting plate. Overall, however, efforts at ERI in the modeling of mantle flow are not as well developed as the observational and laboratory research. Modeling efforts could be strengthened by closer interaction with the very successful observational and laboratory groups that provide the foundation for understanding convection in the Earth. Perhaps emulating the approach of the new Center of Large-scale Earthquake, Tsunami and Disaster would be productive, i.e., developing computational platforms that would allow the integration of various observations into a "community model" that would be relatively easy for collaborators to use to test convective scenarios.

Pillar 4: Development of innovative observational technologies

1. Development of new technologies is quite important because truly new discoveries always come through the gates opened by new technologies. Such developments of new technologies, however, usually take time and young researchers tend to hesitate to engage in such time-consuming works. We were quite impressed to observe some early-career researchers at ERI taking on such challenges in new technology developments leading to successful innovative products.

2. In particular, CHEER (Center for High Energy Geophysics Research) has developed quite unique observational technologies using cosmic rays and invented many innovative instruments one after another, which have already proved useful to obtain important geophysical information.

3. The external review of ERI conducted in 2009 had recommended that the developments should assess the needs from the practical observation research. Most of the new technologies developed at ERI follow this recommendation. We encourage that this direction will continue.

4. Various new simulation techniques have developed at LsETD (Research Center for

Large-Scale Earthquake, Tsunami and Disaster). Although they are not "observation technologies," they are still important as they are expected to open the gates to new research fields. Developments of new software are also important as well for the observational instruments that produce vast amount of data that should be processed efficiently, in particular for real-time needs.

5. ERI has a long and unique history of developing ocean bottom sensors, which have been used in many universities and research organizations. Without the instruments they developed, we would have failed to understand geophysical characteristics of the 2011 Tohoku earthquake. The 2011 earthquake showed that even the plate boundaries close to the trenches, which had been believed to slip only aseismically, can cause earthquakes. Clearly, the development of ocean bottom sensors which can be operated close to the trench axes deeper than 7000 m is very important to reveal the characteristics of huge interplate earthquakes accompanying tsunamis.

6. Other new technologies including compact tiltmeters, optical fiber transducers, rotational seismometers, unmanned radio-controlled helicopters, or autonomous underwater vehicles have potentials to obtain new important data. We trust ERI will make strategic and accountable decisions to turn innovative ideas into actual working instruments in response to scientific needs.

Pillar 5: Development of disaster prediction science, as comprehensive science

1. We applaud ERI for leading the field of earth science at the same time as contributing extensively to disaster prevention and mitigation. The Japanese islands are constantly at risk of natural disasters from earthquakes and tsunamis, and volcanic eruptions. For example, the high risk of a giant Nankai Trough earthquake as assessed by the Central Disaster Management Council of the Government of Japan calls for ERI and other relevant institutions to make concrete and positive contributions for disaster mitigation. There will therefore be no change in ERI's work to move forward on this goal. This challenging mission is one of the five Pillars of SP2009 and SP2009R and we recognize that this is a key direction for a leading research institute in Japan.

2. The Research Center of Large-scale Earthquake, Tsunami and Disaster (LsETD) was established in 2012 after the painful 2011 Tohoku disaster. The uniqueness of this research center is its role in pioneering computer simulation as a new academic field

that combines ‘science’ and ‘engineering’ using massive numerical computation. They seem to be already making rapid progress in the new scheme of joint interactive efforts by scientists and engineers in constructing a large-scale simulation environment for earthquakes, tsunami and disasters. In the coming years, we expect this research center to make useful and immediate contributions to disaster prevention and mitigation. We trust that ERI will manage the LsETD to adapt and evolve with the advancement of high performance computing and to discover new ways to predict and mitigate disasters.

(2) Addenda to science plan 2009

The 2011 Tohoku Earthquake and Tsunami Disaster was the impetus for drafting SP2009R. An immediate issue was how to cope with infrequent but massive natural disasters. SP2009R emphasizes the need for interdisciplinary and international approach. SP2009R also proposes to construct a ”community model” that integrates observations and disaster predictions.

We generally support the direction of SP2009R, which was carefully drafted after the self-evaluation of ERI according to the SP2009. ERI had concluded to maintain the five Pillars, while making additions and emphasizing a more integrative approach through expanding its observational capabilities and applying them in Japanese islands and surrounding oceans, connecting with global observations and synthesizing them via scientific “community model” exercises.

The 2011 event taught us that earthquake faults and volcanoes do not exist independently, but instead require an integrative view of the tectonics prevailing over the Japanese islands, which are, in turn, affected by global dynamics. We have seen several attractive projects being planned, but their implementation plans were not clear. We do not doubt the firm determination of ERI, and we recommend ERI to show leadership in organizing actual international and interdisciplinary large-scale projects with concrete implementation plan based on SP2009 and SP2009R.

(3) Administration of the Center for High Energy Geophysics Research (CHEER) –Present and Future

CHEER was established in 2010 with a 6-year term. ERI has made the right decision, as evidenced by the rapid advancement of the new field led by CHEER and an excellent

publication record based on innovative experiments applied to imaging volcanoes and other target objects. We enthusiastically endorse this direction of muography accompanied with further R&D utilizing scintillation and nuclear emulsion technologies**.** Muon telescopes of larger area and higher background rejection, suitable to uneasy environments, are needed to explore larger rock thicknesses and/or reduce the data taking time for studies of the time evolution of the phenomena. We understand that the researchers recognize the challenge to push the limit of spatial resolution and reaching deeper depths.

We also support their plans to observe atmospheric neutrinos and geoneutrinos to investigate and verify directly the composition of the deep interior of the Earth.

CHEER can play a leading role in expanding international collaborations with a common effort in the R&D on detection technique(s), construction of the experimental apparatus and development of methodologies, in view of objectives in volcanological or other applications.

We strongly recommend ERI to find ways to renew the term of CHEER so that CHEER can play a key role in international collaborations. We also recommend timely reviews to be made for the effectiveness of the science utilizing elementary particles.

(4) Management and Future Plans for the Research Center of Large-scale Earthquake, Tsunami and Disaster

It is highly evaluated that this center was established based on the lessons learnt from 2011 Tohoku earthquake that occurred due to the subduction of the Pacific Plate. Interplate subduction earthquakes that threaten Japan include those that occur along the Nankai Trough, which are caused by the subduction of the Philippine Sea Plate underneath southwest Japan, and also postulated earthquakes that occur directly beneath the Tokyo metropolitan area due to the complex interactions of the Pacific and Philippine Sea plates with the main island Honshu. Although the establishment of the Research Center postdated the 2011 disaster, we consider the establishment of this research center to be timely and expect the center to make important contributions to disaster prevention and mitigation of earthquake hazards.

The fusion of earth science and earthquake engineering is a critical issue from the viewpoint of disaster mitigation: it is an important mission of ERI's. Research initiative of the center as presented shows a clear direction underpinned by a concrete design for the aimed fusion.

We recognize that ERI is determined to be the driving force of the much needed nation-wide collaboration on numerical simulation research and of promoting the integrative

and interactive approach of science and engineering. The center is recognized to be or become a core of computational science combining earth science and earthquake engineering and is expected to play a dominant role in disaster prevention and mitigation. At the same time, it is necessary that the center continuously make effort to improve the computing environment and develop various computational techniques with support of ERI and/or the University of Tokyo.

(5) Management of ERI

ERI management policy is well functioning for basic missions of the institute concerned with researches on earthquakes and volcanic eruptions together with their disasters. ERI has strategic research pillars of five components, which concern earthquake phenomena, volcanic phenomena, earth's internal activities, observational technologies, and disaster mitigation. These pillars were defined in SP2009. These are categorized research targets and are performed by many basic research divisions and mission oriented research centers together with supporting science management centers and supporting staff.

We focus here on the personnel and budget aspects of ERI management. The goals described in SP2009 and SP2009R require a good balance of dedicated researchers and supporting staff (from this perspective, the decrease in technical staff is a worrisome factor). We understand it is not easy even for a leading research institute such as ERI with considerable societal accountability to maintain/increase the staff and sound demography. We also understand the university headquarters regulations impose further constraints in hiring new faculty positions. In order to take advantage of the university's direction towards encouraging new and emerging fields, it seems that ERI's SP2009 and SP2009R fits well to promote new initiatives such as was accomplished by the establishment of LsETD. The role of the human resources planning committee (HRPC) membered by six faculties led by the director seems quite important.

In the current global economical trend, any request for funding considered as "business as usual" does not generally attract attention by the decision makers. Adopting new integrative and trans-disciplinary approaches for the goals described in the SP2009 and SP2009R that do not conform to the conventional school may not only appeal to the funding agencies but also yield groundbreaking results. We encourage ERI to consider seeking this approach.

(6) Performance as Joint Usage/Research Center

ERI has played an important role in the promotion of the researches relating to earthquakes and volcanoes as the only one “Joint Usage/Research Center for Earthquake and Volcano Science” in Japan since 2010[3]. The performance of ERI as the joint usage/research center is considered to be very high as evaluated by the Council of Science and Technology of MEXT in 2013.

In particular, "Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions[4]", which started in 2009 with a long preceding history could not have been promoted. Moreover, the new "Promoting the Earthquake and Volcano Hazards Observation and Research Program" (2014-2019) with more than 20 participating institutions around Japan would not have started without their dedicated efforts. Since the new program needs more and stronger collaboration among participating universities and institutes, we recommend ERI to carefully oversee more than ever the staff with heavy duties for the promotion of the new program.

(7) Human resources and education

ERI faculty continues activities of follow-up system for assistant professors and also development of human resources and education promotion office for postdoc and undergraduate student. These activities are very important for implementation of ERI science plan and development of early-career human resources in the solid earth science field. In particular, we encourage the following activities:

1. Continue the activities of follow-up system and DEP (Office of Developing human resources and Education Promotion) with the participation of many faculty members.
2. Continue the activities of international internship to strengthen the international relationship with foreign students.
3. Continue education of graduates and undergraduates including seminars, lectures, primary experiments, and field trips.

We commend all the efforts that are going into these activities despite many obstacles often imposed from outside. We understand ERI is working with the university

[3] JU/RC scheme was established in July, 2008 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

[4] National Program for earthquake prediction research started from 1965 and for prediction of volcanic eruptions from 1974, which were merged in 2009. The programs run in 5-year series combined with the check and review of the Council of Science and Technology of MEXT.

administration to make changes to improve the situation in particular the support for masters course students. We encourage ERI to seek new ways to recruit PhD students such as through allowing for more interactions with ERI assistant professors. As had been pointed out in the previous external review in 2009, we do not observe significant improvements in gender balance or in hiring of non-Japanese staff.

(8) International and outreach activities

ERI outreach office is well functioned and continuously performs the activities by the means of websites, open lectures, printed matters, and also provides scientific information on disaster prevention to the national and local governments. These activities are important to keep the high level of up-to-date information based on scientific grounds openly available to the public. It is expected that these efforts will help raise the scientific literacy of the general public as well. Thus, we suggest the following:

1. Continue the high level outreach activities to the public, pre-university students and also officers of governances.
2. Continue the high level activities of international long term and short term invitation programs and exchange program to strengthen the international outreach and cooperation researches.
3. Continue the high level activities of international collaborative researches based on formal agreements (MOUs) and also through international programs such as SATREPS[5], IODP[6] and others.

In view of the SP2009R, which emphasizes the enhancement of international partnerships, we expect further international collaborative activities will be organized by ERI.

[5] Science and Technology Research Partnership for Sustainable Development jointly funded by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA).
[6] International Ocean Discovery Program is an international scientific ocean drilling program (2013-2023).

Report of Organizing Committee

External Review Organizing Committee

1. Overall Schedule

June 2013 ERI Faculty Council decided to conduct External Review and appointed External Review Organizing Committee
July 2013 External Review Organizing Committee was organized
August 2013 Working group for external review material was organized
November 2013 Members of External Review Committee were assigned
January through May 2014 Documents for External Review were prepared
May 2014 Documents were sent to Committee members with request of preliminary evaluation reports
June 2014 External Review Committee meeting was held at ERI
July through September 2014 External Review Report was composed and submitted

2. Documents for External Review

The following documents were prepared for the review and sent to all the committee members

[1] External Review (Japanese version and English version)

Research activities were summarized for each Division and Center in a similar way to annual reports. Chapters for Organizational Management Structure, Personnel Structure, Budget, Developing Human Resources and Education, Outreach and Public Relations, International Earthquake and Volcano Research Promotion, Joint Usage/Research Center for National Universities were newly composed. Priority Evaluation Items were also included. This document was created by digital contents including many figures, tables, and links to outside WEB contents. Printed material was not produced.

[2] Activities of Researchers and Technical staffs

Research, education and other activities of ERI researchers (professors and posdocs) and technical staffs performed in 2012 and 2013 were compiled. The document is written in English and Japanese.

In addition to the above,

- Overview of ERI (48 page booklet)
- Report of 2009 External Review

were distributed to all the members during the meeting.

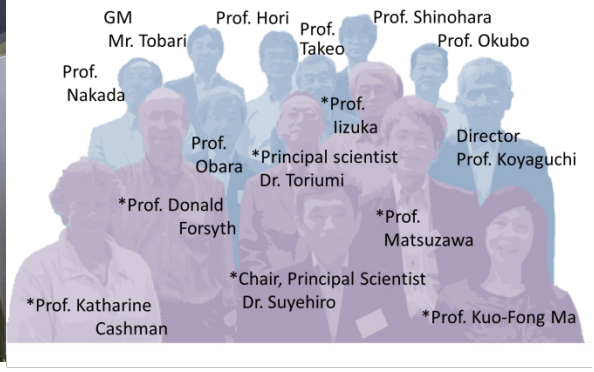
3. Member of External Review Organizing Committee

Kazushige Obara (Chair)
Shuhei Okubo
Masanao Shinohara
Setsuya Nakada
Muneo Hori
Takehiro Koyaguchi
Masayuki Tobari

4. Member of working group for external review material

Kazushige Obara (Chair)
Minoru Takeo
Hiroshi Tsuruoka
Wijerathne Maddegedara Lalith Lakshman
Shigeki Nakagawa

Review Committee members and ERI hosts



(※Red and blue represent Review Committee members and ERI hosts, respectively)

Review Committee meeting (Opening remarks by ERI director)

Open discussion on Science plan and results

Lab tour for the Research Center of Large-scale Earthquake, Tsunami and Disaster

Lab tour for Ocean bottom observation

Lab tour for Center for High Energy Geophysics Research