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NATURAL DISASTER MITIGATION

—A Scientific and Practical Approach

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the InterAcademy Panel on International Issues

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The InterAcademy Panel on International Issues

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Foreword

The catastrophic tsunami in the Indian Ocean on December 26, 2004 inflicted tremendous losses in human lives and properties upon the coastal countries. As part of the response to the major natural disasters, the InterAcademy Panel on International Issues (IAP) launched the "Natural Disaster Mitigation" Initiative in early 2005 in order to alleviate the impact of natural disasters through scientific and technological means, review the applications of science and technology in natural disaster relief, and set the course for future endeavor for the scientific and technological community. The Project led by the Chinese Academy of Sciences (CAS), was joined by academies of Bangladesh, Cuba, Japan, the Netherlands, Sweden, and the United States, followed later by their counterparts in Australia, Canada, India, and Nigeria, etc. Based on this, the Natural Disaster Mitigation Study Panel of IAP was formed in April, 2005.

The Study Panel has completed this detailed and insightful research report through several years' unremitting efforts. Noteworthy is the fact that during the execution of the project, a number of natural disasters of great severity occurred in several countries successively. These catastrophic events have deepened our belief in the significance of the "Natural Disaster Mitigation" initiative and alerted us to the importance and urgency of applying science and technology to natural disaster mitigation, which calls for concerted efforts by all mankind. The scientific and technological community should vigorously carry out the research in natural disaster relief through scientific and technological means, minimizing the damage caused by natural disasters through knowledge innovation. So far, extraordinary achievements have been scored worldwide in terms of disaster relief, leading to remarkable benefits, in which science and technology have been playing a prominent role.

Though damages arising from natural disasters are on the rise due to the vigorous and intensified development of the economy and society, as well as climate change, human casualties have declined because of a GREATER understanding of the disaster mechanism, and the improvement of the monitoring system and growth in our forecasting capabilities. On geological disaster relief, significant progress has been made in the application of effective engineering approaches to disaster prevention.

However, due to the lack of effective forecast capacity with respect to earthquakes, tsunamis and landslides, the human casualty and property losses are disastrous. The global scientific and technological community should cooperate and make joint efforts to overcome all the scientific and technological hurdles to natural disaster relief. Moreover, cooperation and exchange should be strengthened in research on disaster mechanisms, monitoring and early-warning efforts, risk evaluations, disaster forecasts and defenses against natural disasters, and the sharing of disaster information provided by space-based monitoring. Special attention

should be paid to assisting developing and underdeveloped countries in the promotion of disaster relief technologies so as to enhance their risk management and rapid reaction capabilities.

Upon the publication of this report, we would like to express our sincere thanks to the Study Panel of Natural Disaster Mitigation Project and participating member academies for their earnest efforts in completing such a quality research report. We firmly believe that the report will play a positive role in international disaster mitigation.

Professor Chen Zhu

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Co-Chair, InterAcademy Panel
on International Issues

Professor Howard Alper

Chair of the Government of Canada's Science,
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Preface

The great earthquake that occurred in the Indian Ocean on December 26, 2004 caused an unprecedented large tsunami, which successively struck more than ten coastal countries and resulted in about 300,000 deaths and severe economic losses. The whole world was shocked by the tsunami and governments and scientific community all over the world were forced to reflect on the issue: how could mankind effectively utilize science and technology to cope with similar serious natural disasters? Many international efforts have been made to explore the serious problem. The InterAcademy Panel on International Issues (IAP) took prompt action. The IAP co-chairs, Prof. Yves Quéré and Prof. Chen Zhu, issued a written proposal appealing for the joint actions of the IAP community to deal with tsunami and other serious natural disasters, which won warm support from IAP member academies.

The IAP approved an initiative entitled "Global Natural Hazards and Disaster Reduction" at its executive committee meeting held in Stockholm in February, 2005. The study panel, in which the scientists came from a few national academies, finished the work (Phase I) in September 2005. At the IAP EC meeting held in Shanghai in October 2005, the title was changed to "Natural Disaster Mitigation". Thus IAP approved the initiation of the Phase II research work and encouraged the participation of more national academies.

Since 2006, the study panel has held series of international workshops and meetings, and the disaster reduction work of IAP has been effectively advanced. Questionnaire survey in the subject of natural disaster reduction was disseminated to the IAP member academies through the IAP secretariat. A dedicated IAP disaster mitigation project website and FTP site were set up accordingly.

The report of IAP's natural disaster mitigation initiative has been completed after 3 years' dedication. It is worth mentioning that many serious natural disasters have occurred around the world during the initiative. Hurricane Katrina happened in the Gulf of Mexico in 2005, leading to enormous economic losses and over 1,400 deaths in the USA. In 2007 a huge landslide in the Philippines induced by the heavy rainstorms took several thousand lives instantly. In the same year an earthquake in Pakistan caused nearly 80,000 deaths. Hurricane Nargis hit Burma in May 2008, resulting in over 130,000 fatalities. Immediately afterwards a massive earthquake in Wenchuan, China caused tremendous economic losses, and 69,000 people died while 18,000 were missing. It shows the necessity of the IAP disaster mitigation initiative and the long way yet to go in the battle between mankind and natural disasters. Disaster mitigation through science is a subject of enduring significance.

The report mainly covers three natural disasters including earthquake, tropical cyclone and storm surge, and flood and drought, which

cause greatest human and economic impact. We divide these disasters into two types: the first is where the occurrence mechanisms are relatively clear, such as tropical cyclone, storm surge, flood and drought; and the second type, such as earthquake, where the occurrence mechanism is still not yet clear. When addressing the former disasters, in addition to further strengthening the mechanism study, we should pay closer attention to the research in forecasting techniques, strengthen the medium and long term forecasting ability, and enhance the construction of monitoring and pre-warning technology to a greater extent. For the latter disasters, we should deepen and broaden the study of the occurrence mechanism, explore the forecasting methods, carry out comprehensive interdisciplinary studies, improve the ability of collecting and extracting abnormal information of nature, as well as the ability of comprehensive analysis and scientific judgment. There are many kinds of technologies for natural disaster mitigation, but earth observation is recognized as one of the most effective means. This report gives a description and analysis on this point. Meanwhile, we also took the emergency monitoring and assessment of earth observation on Wenchuan Earthquake as a special case study in the report.

Disaster mitigation is a systematic issue which includes basic scientific research, disaster risk assessment, technical support system development, construction of monitoring and pre-warning system, disaster management, and education, etc. Disaster mitigation involves not only national governments, but also international organizations, as well as the community and its members. This report puts forward scientific recommendations on the issue of natural disaster mitigation.

Mankind should fully utilize scientific and technological means to mitigate natural disasters, among which the scientific understanding of natural disasters is of great importance. While we recognize that phenomena now considered disasters have occurred throughout the earth's 4.5 billion years, and helped to form our planet, the growth of human life on the planet has increased the significance of such events. Human activities impact on the natural world, and in the face of natural disasters, mankind should adopt the philosophy of man's harmonious coexistence with nature. Questions such as how natural disasters will change in the context of global warming, and how mankind should adapt to the change or mitigate such situations are waiting for us to explore and solve. As the saying goes, "The way ahead is long! I see no ending, yet high and low, I'll search with my will unbending". The scientific and technological circle must shoulder the responsibility for in-depth research on the relation between global change and natural disasters.

Finally, I would like to take this opportunity to express my gratitude to everybody for their effective work and unselfish devotion to the publication of this book. First of all, I am deeply indebted to IAP co-chairs Prof. Chen Zhu and Prof. Howard Alper, former IAP co-chair Prof. Yves Quéré, and all of the Executive Committee members for their constant guidance to this study over the past few years. I am grateful for the project supporting organization—Chinese Academy of Sciences. I thank my study panel colleagues from different countries. Special thanks go to Mr. Wang Zhenyu, Dr. Lars Hernroth and Ms. Ling Thompson, who have made painstaking efforts to edit the work. My thanks also go to my colleague and friend Prof. Wang Angsheng, who retired when the second phase started. However, the great deal of work he did in the first phase laid solid foundation

for the completion of the whole project. My heartfelt appreciation goes to my colleagues at the Center for Earth Observation and Digital Earth (CEODE), CAS, who have done a large amount of substantial work and coordination for the implementation of the project, especially Dr. Feng Qiang and Ms. Liu Jie.

Prof. Guo Huadong

Center for Earth Observation and
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Chair of Study Panel
IAP Natural Disaster Mitigation Project

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The Study Panel thanks the InterAcademy Panel on International Issues, especially IAP co-chairs Prof. Chen Zhu and Prof. Howard Alper, former IAP co-chair Prof. Yves Quéré, and the IAP Executive Committee, for recognizing the urgency of the topic and providing the opportunity to undertake this important study.

The Study Panel acknowledges the many individuals and organizations who have shared information and provided suggestions that have helped shape the report.

The Study Panel would like to express sincere gratitude to the Science Academies that responded to the questionnaire circulated by the Study Panel: Albanian Academy of Sciences, Chinese Academy of Sciences (CAS), Academia Sinica, National Academy of Exact, Physical and Natural Sciences (ANCEFN) of Argentina, Australian Academy of Science, Cuban Academy of Sciences, The Academy of Athens, Indian National Science Academy (INSA), Science Council of Japan (SCJ), Academy of Sciences Malaysia, Academy Council of the Royal Society of New Zealand, Pakistan Academy of Sciences (PAS), Royal Swedish Academy of Sciences (RSAS), as well as the scientific organizations from Jamaica. Their input and suggestions are woven throughout the report. The working group wishes to thank ICSU (International Council for Science) and AASA (Association of Academies of Sciences in Asia) for their support and cooperation.

The Study Panel is grateful to those who participated in the several workshops held over the course of this project. These participants provided valuable insights that identified major strategic challenges and opportunities, which effectively helped the Study Panel in guiding its deliberations and in the drafting of this report. The workshops included:

- International Workshop on "Natural Disaster Mitigation", September 29-30, 2005;
- The 16th Thailand CODATA DSAO Task Group Conference, January 12-13, 2006;
- International Workshop on Natural Disasters & Emergency Management, September 22-24, 2007;
- Joint Conference by CODATA TGs, IAP, and UN GAID, December 4-5, 2007;
- IAP International Workshop, May 24-26, 2008.

The study panel also owes a special debt of gratitude to the following CAS members and senior administrators for their thought-provoking and strategic advice to the program: Prof. Sun Shu, Prof. Ding Yihui, Prof. Fu Congbin, Prof. Jiang Jingshan, Prof. Liu Changming, Prof. Shi Yaolin, Prof. Xu Jianmin, Prof. Ma Zongjin, Prof. Mu Rongping, and Prof. Cao Jinghua.

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Executive Summary

Background

The devastating Indian Ocean tsunami of December 2004 highlighted the lack of preparedness and lack of data-sharing among the affected countries. Nearly a quarter of a million people lost their lives, and over 1.6 million were displaced from their homes. In the aftermath of this shocking event, IAP members decided to activate the Academies and their scientists in efforts to increase international cooperation in research, data-sharing and application of modern technology for disaster mitigation.

As proposed by the Chinese Academy of Sciences (CAS), agreed upon and approved by the IAP Executive Committee Meeting in February, 2005, the IAP initiative on "Natural Disaster Mitigation" was launched as an IAP response to the Indian Ocean tsunami and more generally to natural disaster mitigation. CAS was to act as the lead Academy for the initiative and member academies from Bangladesh, Cuba, Japan, the Netherlands, Sweden, U.S., and Indonesia joined the initiative.

The six member academies quickly nominated their experts to join the working group. Later on, experts from Canada, Australia, Norway, Nigeria and UN assisted in the initiative.

Between 2005 and 2008, a number of workshops were held, which formed task groups to work on establishing and sharing natural disaster databases, and ensuring their management, standardization and quality control. CAS also held training courses on disaster management and mitigation for scientists from developing countries.

Since the start of this initiative, several natural disasters have occurred, such as Hurricane Katrina in the USA, Hurricane Nargis in Myanmar, and the Wenchuan Earthquake in Sichuan Province of China. These devastating disasters, resulting human suffering, and the socio-economic set-backs caused by these events clearly showed the need for increased international cooperation in disaster preparedness, data collection and sharing, and public awareness.

The Working Group decided to produce three documents. The major report provides scientific descriptions of earthquakes, tropical cyclones, storm surges, floods and droughts, selected for study due to the extent of their destructive power and numbers of lives affected. The report also covers international disaster reduction activities and technological applications for natural disaster mitigation. It has the specific purpose of providing a scientific and practical guide to Academies of Sciences, with examples of good practices in implementing mitigation measures. It contains recommendations for actions where the Academies can play a vital role, and thus support other international activities such as the planned ICSU programme for Integrated Research on Disaster Risk.

The second report is an Executive Summary of the Report, with a final Statement of Recom-

mendations to IAP being produced.

Scientific Understanding of Natural Disasters

Natural hazards resulting from geophysical and hydrometeorological events are uncontrollable forces that impact the environment in which we live. Earthquakes and volcanic eruptions can alter the earth's topography, while flooding and drought have a great impact on life forms. Often, hazards become disasters that cause human and economic losses, and the magnitude of these losses is increasing. Complex infrastructure, population growth and widespread poverty are some of the reasons, but human activities such as land use practices exacerbate the effects.

This is evident both in developing and developed countries. Further, there is now convincing evidence that climate change is contributing to an increasing frequency and intensity of some types of events.

However, as we prepare to meet these changing hydrometeorological conditions, we must use science and technology to explore the potentially positive aspects of a changing climate.

Lack of scientific and technological tools or experience cannot explain why so many of the hazards become disasters. Knowledge, experience and tools exist, but there is a problem of access to, and sharing of, information and data, and a need for science to be incorporated into social and political decision-making. To reduce risks and vulnerability, to mitigate the effects of natural disasters, and to improve rescue operations, a multi-disciplinary approach is necessary, where we accept the need to involve natural, social and political sciences. These issues are of global concern.

Survey on Natural Disaster Mitigation

To determine the level of natural disaster mitigation work around the world, the IAP Working Group distributed a questionnaire to the member academies of IAP. To date, 14 replies have been received from Academies in Cuba, India, Malaysia, Argentina, Jamaica, Japan, Chinese Taipei, China, Greece, Albania, Australia, New Zealand, Pakistan and Sweden. The questionnaire had 15 questions in 5 categories, covering the evaluation of natural disaster mitigation, general severity estimates of major natural disasters, research activities in these areas, public education and emergency response system infrastructure, and best practices. The analysis of the answers showed that: basic scientific research on natural disaster mitigation is critical; the most hazardous major natural disasters are floods, storms, droughts and earthquakes, including tsunamis; the research work is mostly financed by governments and conducted by professional agencies and academic institutions. Only one-third of the replies indicated that financial support was sufficient. International cooperation programmes are, however, being carried out, especially between developed and developing countries.

The questionnaire and the analysis, are presented in the main report.

International Activities in Natural Disaster Mitigation

As natural disasters have become major threats to human life and the world economy, governments and international organizations are cooperating to promote global and regional risk management, and to improve the capability to mitigate the effects of disasters. Early international disaster reduction activities can be traced back to the International Decade for Natural Disaster Reduction (IDNDR, 1990-1999). It raised awareness of the significance of natural disaster reduction. In 1994, the First World Conference on Disaster Reduction was held in Yokohama, Japan, establishing the guiding principles for the Decade for Natural Disaster Reduction. In December, 1999, the UN General Assembly adopted the International Strategy for Disaster Reduction (ISDR) to implement follow-up action for the achievements of the decade, and to promote the continuing development of disaster reduction around the world. Then, in 2005, the Second World Conference on Disaster Reduction was held in Hyogo Prefecture, Japan, and the Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (Hyogo Framework for Action, HFA), was adopted by the Conference, which has become the international blueprint for disaster reduction. In December, 2006, the United Nations General Assembly agreed to establish the "United Nations Platform for Space-based Information for Disaster Management and Emergency Response-UNSPIDER" as a new United Nations programme.

This is a gateway to space-based information for disaster management support, serving as a bridge to connect disaster management and space communities, and by being a facilitator of capacity-building, and institutional strengthening, for developing countries in particular. Along with such UN activities, some regional international organizations and international science and technology organizations have made efforts to encourage regional cooperation on natural disaster mitigation. One of the major European efforts is the International Charter "Space and Major Disasters" initiated by the European Space Agency (ESA) and the French space agency (CNES) in 1999, which aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. Now, the Charter has expanded into a world-wide programme and plays an important role in natural disaster mitigation activities.

In Asia, the most disaster-prone continent, the Asian Disaster Reduction & Response Network (ADRRN) was formed in 2002 after agreement between the Asia Disaster Reduction Center (ADRC) in Kobe, Japan and the United Nations Office for Coordination of Humanitarian Affairs (UN OCHA). This brought together more than 30 NGOs from all over Asia to work together for Disaster Reduction & Response.

Earthquake Disasters

An earthquake is a sudden movement of the Earth's lithosphere (its crust and upper mantle), which is caused by the release of built-up stresses within rocks along geological faults, or by the movement of magma in volcanic areas. Smaller earthquakes occur frequently, but annually only as many as 18-20 reach a magnitude above M_s 7. Approximately 40 disastrous earthquakes have occurred since

the end of the 20th century, and the total death toll is nearly 1.7 million. This number is about 50% of all victims of natural disasters. Most earthquakes (80%) occur in the oceans, mainly in the subduction zones. Earthquakes occurring in such regions are relatively large and they are also deep. These earthquakes can cause tsunamis. Continental earthquakes are less frequent than those in the ocean and they occur mainly on the boundaries of continental plates or the boundaries of active blocks.

Like other disasters, earthquakes and tsunamis can be sudden, seriously destructive, and create long-lasting social, environmental and economic problems. However, compared with weather-related or biological disasters, damage from earthquakes is multiplied by the impossibility of accurate and timely forecasting, and afterwards by difficulty in timely response and rescue efforts.

Earthquake disaster risk zonation is an important tool in earthquake disaster prevention. Developed countries have well-defined a large amount of earthquake disaster zoning and risk assessment maps. It is necessary to evaluate the potential dangers of earthquakes by improving theory and methodology of risk assessment, based on seismic activity and active fault monitoring. It is also crucial to document disaster-caused changes, disaster degree, risk, and loss estimations.

As well, engineering analysis for structural collapse prevention and deformation of buildings in the event of a major earthquake must be put in place everywhere. Related research must continue to be carried out on the seismic structure of active faults, mechanisms of earthquake generation, assessment of potential earthquake activity, and potential losses.

The suddenness and destructiveness of earthquakes often result in rescue decisions being delayed, chaotic, unplanned and unscientific, thus resulting in greater loss. It is critical to improve the means and methods of rescue in all countries. In order to improve the capabilities of emergency response and rescue, research should comprehensively review emergency rescue systems, rapid disaster evaluation technologies, communications, and decision-making methods.

There is also a great need for improved early warning systems. The lack of such a system resulted in the long-distance devastating damage following the Indian Ocean tsunami of 2004.

A systematic assessment of emergency and assistance needs before an earthquake would serve in determining the disaster extent, quantify assistance needed, and establish a disaster planning database and disaster-needs forecast. The resulting disaster aid model can help to rapidly make decisions on the level of assistance within 2-3 hours after large-scale earthquakes and an hour after middle-small-scale earthquakes. The M_s 8.0 Wenchuan Earthquake, for example, caused numerous deaths and injuries, cut off electricity, communications, transportation and water supplies. Major difficulties were encountered at the time for rescue and disaster-relief operations because of the unknown situation on-site. Chinese Academy of Sciences, in cooperation with other Organizations, used remote sensing techniques to work on disaster relief immediately. Through acquiring, processing, interpreting and analyzing remote sensing data, a series of reports on disaster reduction were immediately submitted for

earthquake assistance and disaster relief at all government levels.

Tropical Cyclones and Storm Surge Disasters

Tropical cyclones are warm-core meteorological systems that develop over tropical and subtropical ocean waters, with a surface temperature of 26.5 ℃ or more, and located under areas of small changes in wind velocities with height.

There are, on average, some 90 tropical cyclones annually (including tropical storms, strong tropical storms, cyclonic storms, typhoons, hurricanes, strong cyclonic storms). Their distribution is countered in the northwest Pacific Ocean, the northeast Pacific Ocean, the southwest Indian Ocean, the Atlantic Ocean and Caribbean Sea, and the southwest Pacific Ocean, with of 29%, 18%, 15%, 12% and 12% respectively. Storm surges are caused by tropical cyclones, caused by strong winds and sudden change of atmospheric pressure near their centers. This causes a sudden and sharp rise in coastal water levels.

World Meteorological Organization (WMO) statistics show that tropical cyclones, associated storm surge, and torrential rains are the most destructive hazards in terms of deaths and material losses. According to the Third Assessment Report on Global Climate Change issued by the WMO and the Intergovernmental Panel on Climate Change (IPCC), since 1750, overall climate warming has been a result of human activities. The surface temperature of most tropical waters has already increased by 0.2-0.5 degrees. There are indications that, in the future, tropical cyclones may increase in intensity, although there are uncertainties regarding the overall frequency of tropical cyclones in a warming world. With increasing globalization, it can be inferred that disasters related to typhoons will have increasing socio-economic impact, particularly in developing countries.

In an attempt to reduce the effects of cyclones and storm surges, science and technology have developed surveillance systems and methodologies for disaster prediction and early-warning. These systems of spatial observation technology, supported by powerful computers and telecommunications facilities, have resulted in the development of numerical weather prediction techniques that have permitted significantly-improved real-time forecasts of weather-related hazardous phenomena. Some of the major advances of these sciences include: the availability of an unprecedented amount of new non-traditional observations, in particular from earth observation satellites and imaging radars; considerable progress in the scientific understanding of dynamical and physical processes in the atmosphere and its interaction with the oceans.

Although over the past two decades, several nations have made remarkable progress in typhoon surveillance, forecasting and alerts, there are still material predictive errors of the estimation of storm tracks, and in the accuracy of predicting their intensity, path, wind and associated precipitation of tropical cyclones. Forecasting and early warning systems for storm surges have mainly been established in developed countries, but Cuba and Bangladesh are examples of developing countries where new surveillance and forecasting systems have had very positive impact on disaster mitigation.