National Earthquake Science and Technology Innovation Plan

China Earthquake Administration

April, 2018

FOREWORD

"*...to the planet we know today, with its hospital atmosphere and rich resources, a planet still active inside—as evidenced by earthquakes, volcanoes, ocean basins that open and close, and continents that drift apart.*" [1]

Earth is our only home. During the process of evolution, it bestows us with great fortune for our existence, survival and development. Meanwhile, its movement frequently generates earthquakes, bringing great losses to human lives and properties. China, located between the Indian and Eurasian plates as well as the westward subduction of the Pacific plate and scattered with hundreds of active faults, is one of the most seismic prone countries in the world. Over the past century, nearly 90,000 lives were lost during earthquakes. With the speedy development of industry chains and infrastructure construction, the whole country encounters more challenges from seismic risks. In a highly globalized and technicalized era, the Gray Rhino and Black Swan events will even aggravate the crisis.

To secure the nation from earthquake disasters, for decades, the Chinese government puts disaster mitigation on the top agenda of the government's work. In 2016, 40 years after the *M*7.8 Tangshan Earthquake, Chinese President Xi Jinping highly emphasized the importance of reducing natural disasters, and pointed out that disaster reduction should adhere to the principles of "*preparedness first, combined with resistance and rescue, combination of daily disaster reduction and post-disaster rescue,*

[1] Frank Press & Raymond Siever, *Earth*, W.H. Freeman and Company,1982:3,

from post-disaster relief to pre-disaster preparedness, from response of typical disaster to comprehensive disaster reduction, and from reducing disaster losses to decreasing disaster risks, to comprehensively promote natural disaster prevention capacity of the whole society.", which outlined the focal point of disaster reduction of China, i.e. an integrated dynamic process of preparedness, protection, reduction and relief. Practices show that the development and promotion of these capacities must rely on science and technology innovation, which equip us with a deeper understanding of disaster risks, stronger disaster preparedness capacity, and more informative public service.

China Earthquake Administration, affiliated to the Ministry of Emergency Management of the People's Republic of China, is authorized to take the responsibility of earthquake disaster reduction. It endeavours to fulfil its mandate, among which science and technology is a priority. Seismologists keep making arduous efforts to have a clear understanding of the inner structure of the earth. With their studies, the distribution and migration of the interplate earthquakes is envisioned to certain extent, while the study on intraplate earthquakes is comparatively far behind. This brings the biggest challenge to China, as most of its destructive earthquakes are of intraplate type. Targeting at the featured tectonic and seismogenic background of China, China Earthquake Administration initiated the *National Earthquake Science and Technology Innovation Plan (NESTIP)*, to clearly define the main tasks of the next 10 to 15 years. The plan will focus on four specific programs, i.e., "Crust Imaging", "Earthquake Anatomy", "Resilient Communities" and "Smart Service", with the aim to identify the deep earth structures at fine spatial scales in the Chinese Continent, work out effective measures for earthquake preparedness, provide the public with abundant seismic products, so as to significantly upgrade the capability of reducing seismic risks and protect lives and properties of the nation.

Crust Imaging. Clear understanding of the geological structures is the foundation as well as the cutting edge of earth science. Compared with space exploration, knowledge of the earth and its internal structures is extremely limited, inhibiting seismologists' ability to understand the mechanisms of earthquake occurrence. During

2011 to 2015, China has conducted researches on deep exploration of the earth, and finished a 2-stage deep crustal structure detection and geophysical field observation. 83 large-scale active faults were also investigated, producing an immense amount of observation data. The program will unveil the earth by a comprehensive exploration of crustal structures, especially the deep structure and faults of seismic belts.

Earthquake Anatomy. Earthquake prediction has always been a great scientific challenge all over the world. When reviewing all the historical development of earthquake science, we can find out that it is closely related with the in-depth analysis of the great earthquakes. Study on different types of great earthquakes and analysis of their regular patterns will gradually improve our understanding of seismogenic mechanism. Comprehensive investigations on great historical earthquakes in China have already been conducted. We proposed the theory of "active blocks" and will construct a China Seismic Experimental Sites (CSES), providing a solid foundation for the implementation of "Earthquake Anatomy". The program will anatomize typical earthquakes and propose a numerical model for strong earthquake nucleation using new technology and methods, e.g. big data, cloud computing, artificial intelligence, etc., with the goal to enrich our present theory of strong earthquakes, and gradually deepen our understanding of earthquake occurrence.

Resilient Communities. Seismic vulnerability is one of the core problems restricting the development of sustainable urbanization. During the past years, China has conducted researches on the resilient theory and technology for communities, such as seismic performance design, seismic isolation and mixed experiments. Emergency preparedness and rapid response countermeasures were gradually popularized by communities. The program will assess the national seismic risks and develop advanced aseismic technologies. It will significantly improve resilience of the communities and continuously promote the development of seismic safety throughout China.

Smart Service. Public service is a nut for earthquake preparedness and reduction in China. We have formed a national earthquake rapid-report and information service, and launched the national rapid-report of earthquake intensity and earthquake early warning

system, but gaps like types, timeliness, and technical contents of information products still exist. The program will comprehensively enhance quality of seismic products, improve the service platform, and provide more personalized intelligent services, so as to meet the needs of governments, societies and the public.

With the implementation of the NESTIP, we will greatly improve the observation and exploration of earth's internal structures and geophysical fields for key areas in the Chinese Continent to have a better understanding of the crust, anatomize earthquakes to improve the understanding of regular pattern of earthquakes, develop earthquake disaster reduction technology and countermeasures, construct 10 demonstration resilient cities, and build a high level information platform for earthquake preparedness and reduction.

CONTENTS

1. Challenges

"Crust Imaging" will focus on challenges as follows:

- Understanding the characteristics of crustal and mantle structures beneath Chinese Continent and its adjacent regions;
- Creating high-resolution 3D fine models of the seismogenic environment of representative earthquake areas;
- Understanding the distribution and activity of major active faults in Chinese Continent;
- Monitoring dynamic variations of sorts of geophysical fields in Chinese Continent;
- Understanding the spatiotemporal variations of crustal physical properties on the main seismic zones Chinese Continent;
- Understanding the interaction and related deep processes of active blocks Chinese Continent;
- Researching novel techniques and approaches for exploring the Earth's internal structure and monitoring geophysical fields;
- Integrated Imaging of the Earth theory and applications.

2. Main Tasks

1) Investigation of the Crustal and Mantle Structure in China and Its Adjacent Regions and Major Seismic Zones

This program is to investigate the 3D crustal and mantle structures beneath China and surrounding regions with a step-by-step deployed, large-scale, dense broadband portable seismic arrays across Chinese Continent in a regular grid pattern. It will be a

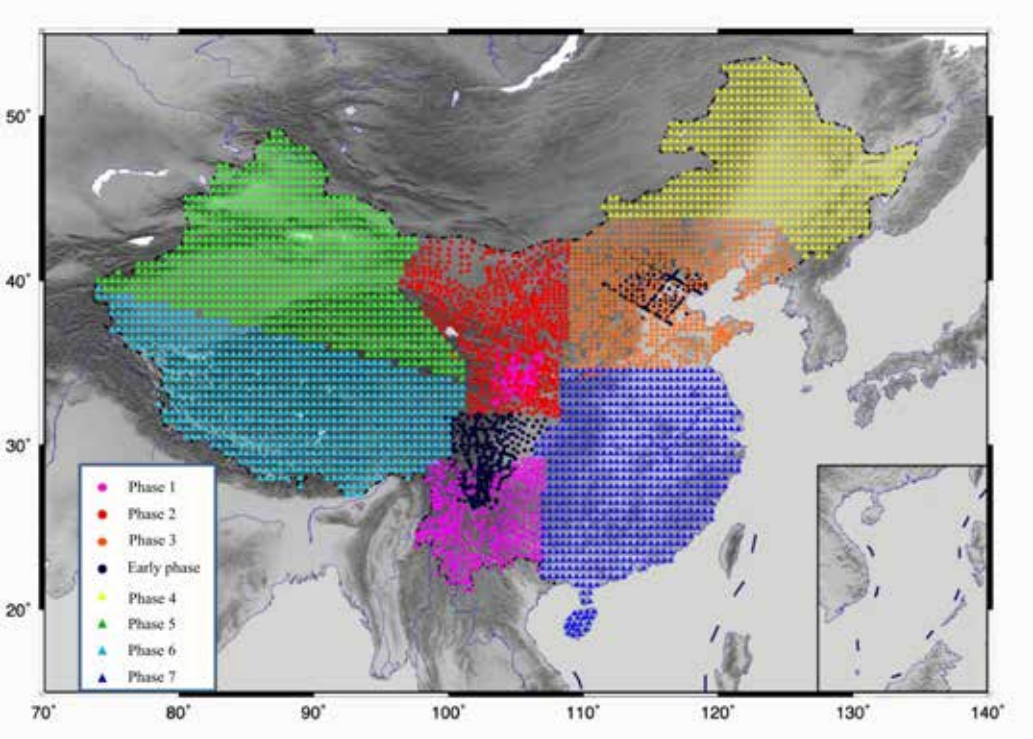

Fig 1. Chinese Continent Crust Structure Exploration Planning

continuation and extension of recent seismic array studies in the North-South Seismic Belt. The array data will be used for integrated geophysical studies including: high-resolution 3D seismic wave velocity structure, attenuation and anisotropic structure of the crust and upper mantle, and the deep tectonic environment hosting strong earthquakes, through the development of new imaging techniques and modeling methods. In cooperation with the Geoscience Transaction Project and the Deep-Earth Project, 12 seismic refraction/reflection profiles with a total length of approximately 5,000km will be deployed to obtain the fine crust and upper mantle structure inside and across the boundaries of important tectonic blocks.

2) Investigation of 3D Fine Structure in Key Regions

Multidisciplinary geophysical observations, including short-period dense seismic array, deep seismic refraction/reflection, magnetotellurics, gravity, magnetic, geodetic surveys, will be conducted to deriver 3D fine structures of crust and upper mantle in the strong earthquake areas. These 3D fine crustal and upper mantle structures will provide enhanced insight into likely seismogenic faults. The National Geostress Monitoring Network will also be utilized to determine the stress fields and their evolutions during the formation and occurrence of strong earthquakes.

Conducting dense seismic array and integrated geophysical studies will aid in detection of areas with the highest earthquake risks. A detailed near-surface model, with a resolution of hundreds of meters in lateral direction and tens of meters in vertical direction, will provide important structure parameters for strong ground motion simulation of earthquakes.

3) Exploration of Active Tectonic Boundaries in Chinese Continent

Large-scale fault mapping and key-area deep to subsurface detection of structures will be carried out along the North-South Seismic Belt, Tianshan Seismic Belt, South China Coast Seismic Belt, and the National Seismic Monitoring and Protection Regions. Distribution of active faults should be provided. Long-term slip activity and earthquake recurrence will be studied and characterized, and regional seismogenic tectonic models will be developed for each of the tectonic regions. A basic database of active fault exploration will be set up. These will advance the research on the current dynamics of intraplate earthquake. Geophysical detection of blind active faults will be conducted for the metropolises around Beijing, Tianjin, and Hebei Provinces. Active fault distribution and seismogenic potential will be provided as the scientific basis for seismic hazard assessments, policy-making for earthquake prevention and mitigation, disaster reliefs, civil planning, and site choice of important engineering projects.

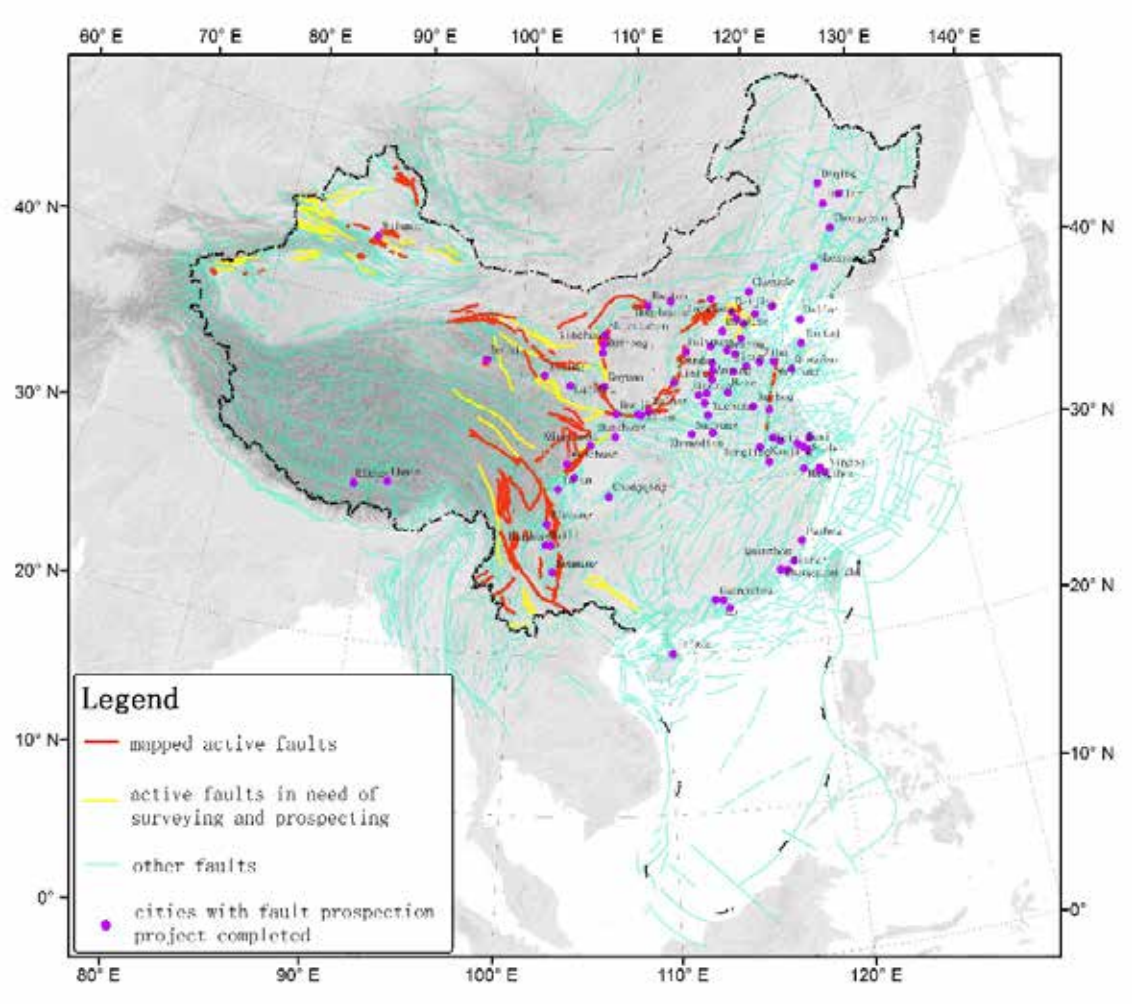

Fig 2. Chinese Continent Active Fault Exploration Working Schematic Diagram

4) Integrated Observations of Geophysical Field in Chinese Continent

A denser 3D observation of crustal movement should be carried out by stages and regions in the North-South Seismic Belt, North China, Xinjiang, and other key areas. On the basis of existing data, images of ten-years scale crustal velocity fields of both horizontal and vertical movements on the key tectonic belt of Chinese Continent will be obtained. To update existing data within the key seismic belts, horizontal and vertical movements will be obtained with GNSS, precise leveling, and InSAR techniques. Based on the National Terrestrial Gravity Network, the terrestrial gravity observations will be carried out in the dense map in order to obtain high-precision signals of gravity changes along the key tectonic belts in Chinese Continent. Conducting regular absolute

three component measurements of the geomagnetic field will be carried out to obtain images of the basic geomagnetic field and variations of the lithosphere magnetic field in Chinese Continent.

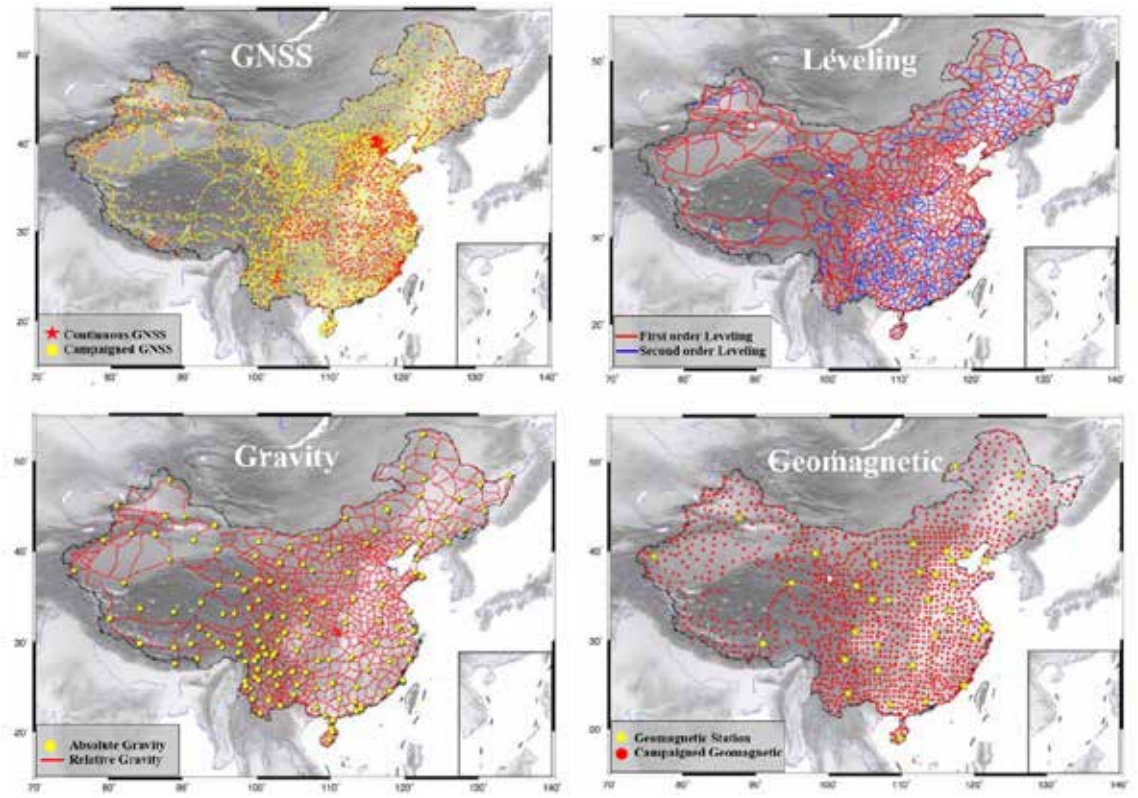

Fig 3. Schematic Diagram Chinese Continent Integrated Geophysical Field Observation

5) Time-lapse Monitoring Using Air-gun Active Seismic Source

To improve the coverage of active Air-gun seismic source, six Fixed Air-gun Signal Transmission Stations (FASTS), as well as related monitoring systems, will be constructed. Currently there are four FASTS and with the additional six FASTS planned, an active monitoring system with 10 FASTS systems will be implemented and will provide monitoring abilities in a majority of the regions in Chinese Continent. We plan to develop algorithms and techniques to better detect and extract weak Air-gun signals that have been covered by high background noise. With the support of repeated signals from active source, the time-lapse images of the subsurface will be produced to investigate the stress distribution and variation, as well as their relationship

with earthquake physical process. Using the data of active sources, high resolution tomography images will be produced in key regions.

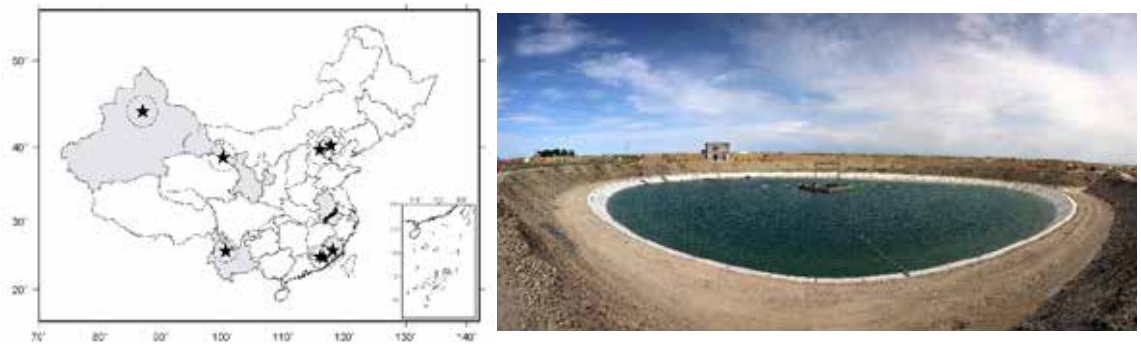

Fig 4. Locations of Air-gun Experiment in China (left) and 50000 Tons Pool of Hutubi Launching Pad, Xinjiang (right)

6) Interaction of the Active Blocks in Chinese Continent and the Related Deep Processes

By integrating all of the basic results from the crust-mantle structure probing, active faults exploration, dynamic variation of the geophysical field, and the 3D structure , the deformation and kinematic characteristics of the active block boundary in the Chinese Continent will be studied. It will be further analyzed to understand the interaction and deformation mechanism of the active blocks, and their coupling relationship between crustal and mantle processes, and mass movement and energy interchange processes. The theoretical framework for strong earthquakes in Chinese Continent based on active blocks will be developed and improved, and consequent dynamic model of active block interaction in Chinese Continent will be constructed.

7) Technology R&D and Data Analysis and Processing

High-resolution seismic imaging technology development based on broadband seismic array should be developed. The synthetic inversion technique of high-resolution geophysical profiles, physical property of crustal medium extraction based on precise and controlled source detection, high-resolution active fault remote sensing detection technology should also be proposed. The method for determining the location of strong earthquakes based on LIDAR, UAV and fault activity study, and routines for

optimizing seismic network and observation system will be developed. The method for integrating all geophysical and geodetic data, including GNSS, InSAR, seismic, gravity, geomagnetism, and geoelectricity, will also be developed.

3. Expected Targets

1) Goal 2020

By 2020, the Transportable Array deployment and two comprehensive profiles across the boundaries of important tectonic blocks and strong earthquake source zones will be completed in the North China region; the 1:50,000 geologic mapping and paleo-seismic study will be conducted for about 40 active faults in the North-South, Tian Shan, Northeast China, and the Southeast Coastal Seismic Zones; the blind active fault identifications and seismic hazard assessments for the cities of Beijing, Tianjin, and Hebei Provinces, will be performed; two Air-gun Transmitting Seismic Stations will be constructed; the comprehensive geophysical investigations for the North-South Seismic Zone and the North China region will be completed; the travel-time table based on the 3D velocity model for the North-South Seismic Zone will be established; a full-waveform inverse-imaging techniques, as well as new method for integrating GNSS, InSAR, and other data, will be developed. The results and techniques will be of international level.

2) Goal 2025

By 2025, the high-resolution 3D structure of crust and upper mantle and 12 comprehensive detailed geological and geophysical profiles across the important tectonic boundaries, as well as the time-lapse images of velocity structure in the surrounding area of the 10 Air-gun Transmitting Seismic Stations, will be completed; the spatial distributions, activity rates, and characteristics of about 200 active faults in major seismic zones will be investigated; the comprehensive geophysical field as well as its evolution with time in China will obtained; and the geo-dynamic model for intra-plate earthquake in China will be established. The outcomes will be of advanced international level.

1. Challenges

"Earthquake Anatomy" will focus on the challenges as follows:

- Typical seismogenic structure model and physical process of earthquake incubation and occurrence;
- Observation of the meta-instability state and its recognition in the field;
- Mechanisms of grouped earthquake activities along active block boundaries;
- Regional seismic probabilistic prediction and numerical simulation using big data;
- New technologies related to detect in seismogenic processes, as well as anti-interference, low-power consumption and standardized instruments of seismic monitoring.

2. Main Tasks

1) Analysis of Typical Earthquake Events and Research on Seismogenic Mechanism of Strong Earthquakes

Detailed case studies of typical strong earthquakes in regions like Haicheng, Tangshan, Wenchuan, and Yushu will be conducted to explore seismogenic models for different tectonic settings in different regions and the deepen the understanding of earthquake occurrence mechanisms. Based on the original observations, we aim at acquiring information on crust and mantle structures, the physical properties of the crust and mantle mediums, modern-day crustal movement, and tectonic deformation in strong earthquake prone areas. By integrating observations in regional deformation, fault activity, stress evolution, pre-, co- and post-seismic processes, and combining with experimental results of rock physics, we will construct better earthquake seismogenic

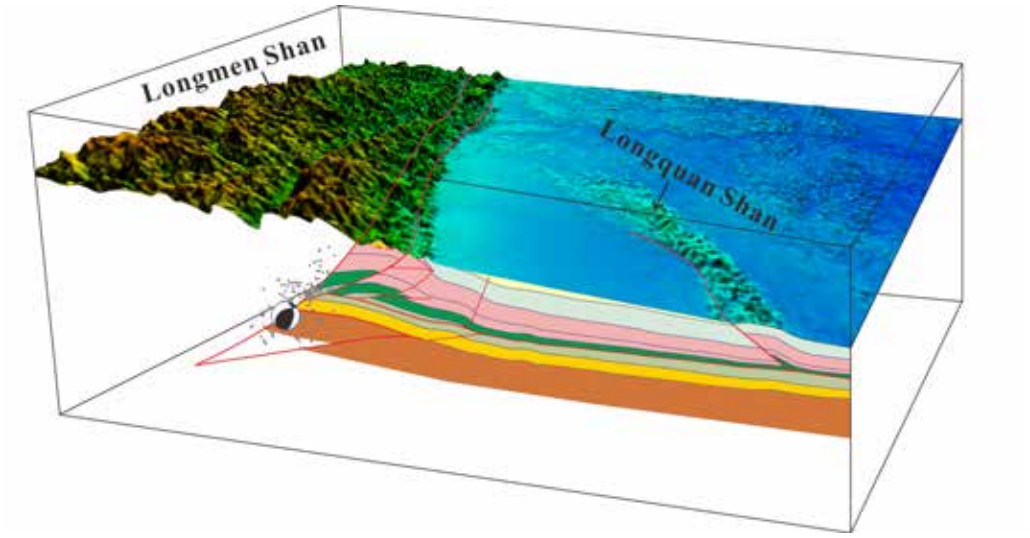

Fig 5. Three-dimensional Structure of Crust and Faults in Longmenshan Area

models, study the mechanism of earthquake genesis, sought physical interpretations of the formation mechanism of observed earthquake precursors, and explore the methodology and technique of strong earthquake dynamics.

2) Observation of the Meta-instability State of Faults and Study on the Mechanism of Earthquake Precursor

The meta-instability stage of a fault is between when the peak stress is reached and the onset of failure, and is the final stage leading to an earthquake. Tectonophysical experiments have shown that accelerated release of stress and synergetic activity of a fault are the crucial characteristics of meta-instability state. Therefore, it is necessary to carry out further laboratory studies on the factors that affect the evolution of faults during the meta-instability state, and establish field observation networks to monitor the meta-instability state of faults at an observation scale. The purpose of current research focuses on the interaction between different tectonic positions and the evolution of the multi-physical fields in a fault. By continuing this research, the hypothesis of fault meta-instability will be developed and tested through laboratory experiments and field observations with aim to provide a foundation for research on earthquake precursors.

The results of this research will be of great significance for revealing the mechanism of earthquakes and determining the critical stages of instability. Furthermore, this research will bring abstract theoretical research closer to reality and promote the effectiveness of earthquake prediction.

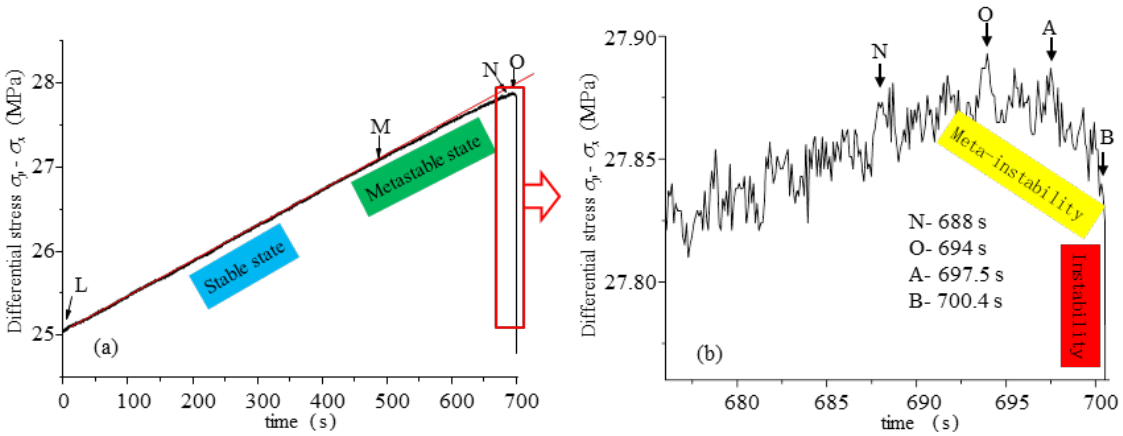

Fig 6. The Curve of Differential Stress and Time

3) Mechanisms of Grouped Strong Earthquake along the Active Block Boundary in Chinese Continent

Dynamic models of the strong earthquake occurrences along the active block boundaries in China and its adjacent areas will be developed from the studies on tectonics, geodesy, geophysics and geodynamics of tectonic block boundaries, including studies on the interaction between the strong earthquakes and the fault zone of the block boundary system, the movement and deformation of active blocks, and crust and upper mantle structure and its variation. The mechanism and evolution pattern of grouped strong earthquake along boundaries of active tectonic blocks will be explored through studies on the interaction between seismogenic structure and boundary faults and the migration and triggering of strong earthquakes.

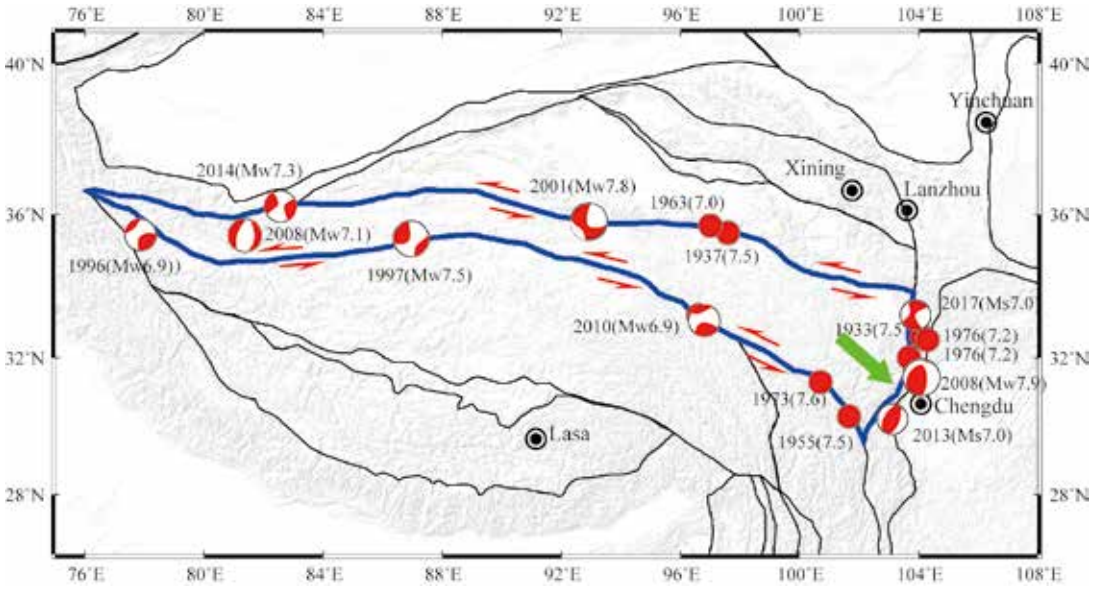

Fig7. Occurrence and Migration of Strong Earthquake Along the Boundary of Bayankala Block

4) Study on Seismic Probabilistic Prediction Method and Physics-based Anomalies Identification

The recurrence patterns and slip rates of the active faults, regional strain rates, and seismicity will be explored to develop physical models of earthquake formation and occurrence and methods of earthquake probabilistic forecasting for the Earthquake Forecasting Experiment Field in Sichuan and Yunnan Provinces, utilizing the comprehensive geophysical, geodetic, geochemical and geological explorations and observations. The anomalies associated the historical earthquakes will be systematically collected and analyzed to explore the relationship between the anomalies and earthquakes. The earthquake precursor mechanism, as well as new methods and technologies for earthquake forecasting for different temporal-spatial scales, will be explored. The identification, characteristics, and mechanism of induced earthquakes will also be explored.

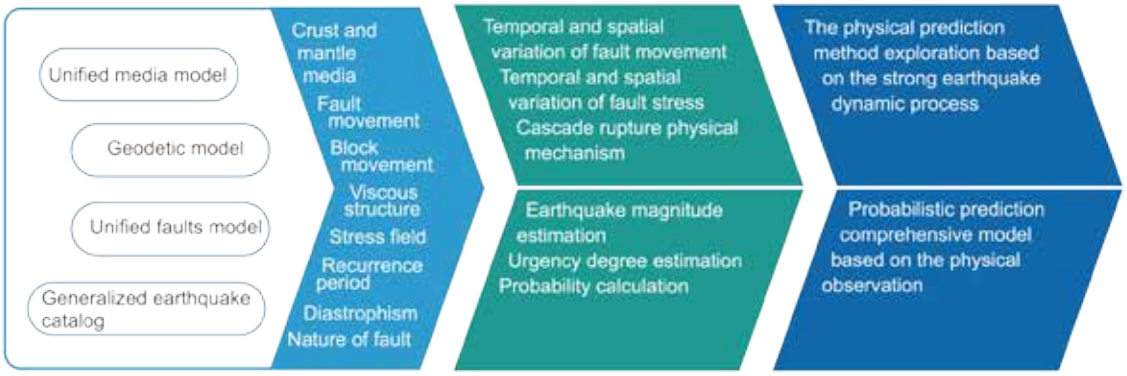

Fig8. Frame Diagram of Dynamics Probability Prediction Model

5) Seismological Modeling Based on Big Data and Super Computing Numerical Simulation

To understand the key parameters in controlling an earthquakes physical process, geophysical, geodetic, geochemical and geological observations will be incorporated through data assimilation. Using inter-discipline observations, the model for earthquake processes will be expressed physically and mathematically using big data. The algorithms and software with application on super computers will be developed to fulfill the computation requirement and used for numerical simulations. The different models will be certified through numerical experiments based on data and toolkits. The modern computing technique, such as Artificial Intelligence (AI), will be explored for their possible applications on earthquake prediction.

6) Advanced Technology and Instrumentation of Seismic Observation

The data from seismic electromagnetic satellite will be processed, analyzed, and used for developing new technologies. The space and ground based multi-angle and multi-band infrared technologies will be used for seismic monitoring and experiment. A series of gravity and electromagnet instruments will be developed for different observational purposes and scales. The instruments of ease deployment and high reliability, such as the integrated stress instruments and buried soil chemical compound analyzer, will be developed. The seismic instruments for high temperature and pressure

environments and techniques and facilities for on-line calibration and data acquisition will also be developed. A new observation system integrated high-frequency GNSS with strong-motion seismograph will be developed.

3. Expected Targets

1) Goal 2020

By 2020, the 2008 M_S 8.0 Wenchuan earthquake will be dissected, and its formation and occurrence mechanism will be presented; the meta-instability of fault will be explored and compared with laboratory experiments and field observations; the preliminary dynamic models for strong earthquake along the active block boundaries in China will be constructed; and the version 1.0 of earthquake probabilistic forecasting model for the Sichuan and Yunnan region will be developed and used to provide the mid- and long-term earthquake forecasting for the region.

2) Goal 2025

By 2025, all selected earthquakes will be dissected to develop the mechanisms of strong earthquake formation and occurrence in China; the criteria and methods for determination of the meta-instability state for active faults will be developed based on the evolution of the meta-instability state and precursor mechanism; the patterns and characteristics of the strong earthquake at the active block boundary will be presented; and the earthquake probabilistic forecasting model for the Sichuan and Yunnan region will be improved (i.e., the version 2.0). Intelligentization and standardization of seismic observation technology will rise to the level of international level.

1. Challenges

"Resilient Communities" will focus on challenges as follows:

- Damage mechanism, structural failure, and site condition;
- Seismic hazard assessment/zonation, and seismic risk assessment/ zonation;
- Seismic hazard chain-reaction evolution, and secondary seismic hazard/risk assessments;
- New materials and techniques, such as seismic isolation for resilient structural engineering;
- Management system for resilient society including land-use planning, performance-based engineering, and intelligent decision-making for emergency response and rescue;
- Evaluation criteria and methodology for resilient cities and towns.

2. Main tasks

1) Earthquake Impacts and Damage Mechanism of Engineering Systems

The methodologies, techniques, and instrument will be developed for recoding strong motions at free fields and on structures. Strong ground-motion nonlinear site response at complex site conditions in particular and structural response and failure will be studied. Research on seismic performance of aging structural elements and members, failure mechanism of urban engineering structures, and infrastructures under complex strong ground motions will be conducted. Multi-scale models for dynamic response analyses will be developed practically and efficiently, and an experimental multi-scale

platform for the simulation of damage effects on buildings and infrastructure will be established, shown in Fig.9.

Fig 9. Large-scale and Large-load Seismic Simulation Facilities

2) Methodology for Seismic Risk Assessments and Its Application

The methodologies for time-dependent seismic hazard analysis and urban micro-zonation will be explored and developed to provide the assessments for different hazard levels and different ground-motion parameters by incorporating the 3D fault rupture models and broad-band ground-motion simulations. The vulnerabilities of various engineering structures and lifelines will be investigated. The methodologies for estimating economic losses and casualties caused by a scenario earthquake ground-motion, or the probabilistic ground-motion, will be developed. The 3D fault models and corresponding databases will be created. The national ground-motion zonation maps with multi-parameters for the land and ocean will be compiled. The earthquake-induced geological hazards zonation maps will also be compiled. The seismic hazard and risk maps in multi-scales for urban agglomerations such as Beijing, Tianjin, and Hebei Provinces, Yangtze River Delta region, and Pearl River Delta region, will be also compiled.

3) Assessment and Mitigation of Earthquake-induced Hazards

The mechanisms of the earthquake-induced hazard chains and mitigating measures will be studied. The earthquake-induced geological hazards such as landslide and debris flow will be investigated. The systems for earthquake-induced geological hazards assessing, forecasting, early warning, and mitigating, will be developed. The damage mechanism and resilience technology of urban fuel pipeline systems under earthquake events will be explored. Generating mechanisms of earthquake-induced fire and technology for the fire spreading simulation will be explored. The spreading mechanism of dangerous chemicals and its risk assessment will be developed. The methodologies for post-event rapid risk assessment for the infrastructures, such as high dams and nuclear power plants, will be explored and developed.

4) Engineering Resilience Technology

The seismic design theory and methods to meet the resilience requirement of complex urban systems and essential industrial facilities will be studied. The damage mechanisms of engineering structures and new damage control technologies will be investigated. Seismic design and performance control technology for non-structural elements and industrial facilities will be explored. New seismic isolation and control technologies and post-earthquake rapid repair techniques, including self-recovering system and replaceable structural members, will be developed, an example shown in Fig.10. The post-earthquake rapid repair techniques for urban lifelines, resilience-based retrofit methods for the existing structures, and performance assessment will be investigated. The technologies for cost-effective and practical constructions of earthquake resistant rural residential houses, including those built with environmental-friendly technology and for ethnic residents, will be developed.

Fig 10. Design Sketch of Kunming New Airport (down) and Elastic Sliding Bearing (up)

5) Social Resilience Supporting Technology

The methodologies for damage monitoring and assessment of engineering sites and major structures will be explored and developed. New technology for earthquake early warning will be developed by utilizing the big data. The emergency response and management for critical facilities such as high-speed rail, nuclear power plant, and dams, will be developed. A new technique for earthquake disaster simulation and visualization will be explored for cities and towns. The new regulations and policies for the earthquake resistant measures of rural residential buildings will be developed and implemented. The seismic risk models and their applications in earthquake insurance

will be explored by considering the seismicity and exposures in China. Based on the models for emergency evacuation of crowd gathering areas, the evaluation system for earthquake emergency response and rescue in urban communities, and an emergency rescue plan system and training supporting platform will be developed. An intelligent and rapid decision-making system for earthquake damage assessment, emergency response and rescue planning and implementing, will be developed.

6) Standards and Examples of Construction for Resilient Urban and Rural Communities

The national standards and evaluation systems for earthquake resilient urban and rural cities will be established. In order to establish examples, seismic risk assessments and building evaluations and retrofits will be performed for ten selected cities to achieve the resilient capability, including the Xiong'an district. The application of the engineering resilience techniques, such as base isolation and control techniques particularly to schools, hospitals, and specific buildings will be promoted. The earthquake early warning systems, seismic resilient monitoring network, rapid information acquisition system through a variety of urban and rural social networks, will be established. Emergency management system for lifeline engineering is also needed to improve. The earthquake emergency rescue decision making system, disaster prevention and mitigation facilities, and emergency support system will be completed. A multidisciplinary experimental site for integrated studies in earthquake engineering, engineering seismology, seismology and soil dynamics will be constructed.

3. Expected Targets

1) Goal 2020

By 2020, the methodologies and models for seismic hazard and risk assessments, as well as large-scale earthquake-induced hazard and risk assessments, will be developed; the new methods including seismic control, structural isolation, and resilience-based seismic retrofits, will be identifies; the methods for damage monitoring and evaluation with different techniques will be developed; and the models and methods for the

community-based earthquake emergency and rescue analyses, and emergency scenario analyses for crowded areas, will be created and implemented.

2) Goal 2025

By 2025, the simulation techniques for the damage process of large-scale engineering structures under earthquakes, and broadband near-fault strong ground motion simulation theory and methodology will be developed; the seismic risk assessment and earthquake insurance models will be developed; the theory and technique for earthquake-induced secondary hazard assessments will also be developed; the new resilience-based seismic design theory, new post-earthquake rapid recovery technique for engineering structures and lifelines, new earthquake early warning technology, and earthquake emergency management methods for critical facilities will be developed; the intelligent assistant decision-making technique for earthquake emergency rescue will also be invented; an evaluation system for assessing the construction of resilient cities and towns, and ten examples of resilient cities and towns will be established; a new and updated version of ground-motion parameter zonation map, earthquake-induced geological hazards map, and seismic hazard and risk maps for key urban agglomerations will be compiled.

1. Challenges

"Smart Service" will focus on challenges as follows:

- Management and sharing of the big data of earthquake science and technology;
- Smart service of the information cloud of earthquake prevention and mitigation;
- Deep mining of the earthquake data resources and development of new products for public service;
- Optimization of earthquake standard system.

2. Main Tasks

1) Construction of a Big Data Center for Earthquake Science

A national big data center for earthquake science will be established to provide a unified and evenly distributed seismic data sharing system throughout the country. All geophysical, geochemical, geodetic, and geologic observational data under the jurisdiction of China Earthquake Administration will be collected, sorted, and achieved in the uniform formats. Systems for automatic data quality assessment, open sharing service, and service efficiency assessment will be established. The applied research to efficiently utilize the earthquake big data will be promoted. A data sharing center for earth science will also be gradually established.

2) Realization of the Cloud+Terminal Smart Service of Earthquake Prevention and Mitigation Information

National earthquake information sharing service system will be established through development of an earthquake information cloud platform for data storage,

business operations, products, information and service. The information on earthquake monitoring, forecasting, prevention and mitigation, emergency response and rescue, and scientific research, including earthquake early warning, earthquake rapid reports, intensity rapid reports, damage assessments, damage rapid reports, refine service of earthquake zonation, invulnerability of structures, knowledge dissemination, and earthquake relief, will be re-structured and unified for distributions and services. The capacity of online storage, computing, and service for earthquake data and products will be improved to achieve the integrated information service.

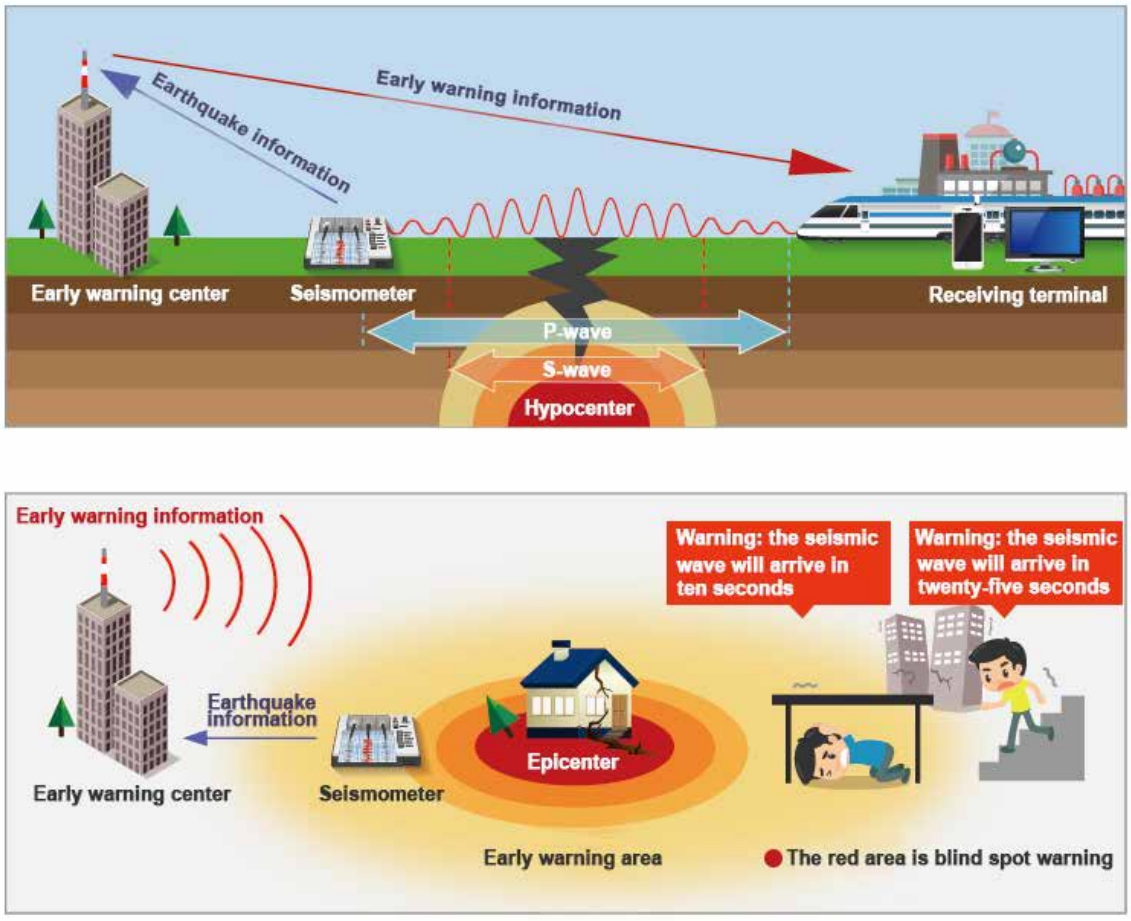

Fig 11. Earthquake Early Warning Information Service Network

The research on the smart service of earthquake information will be explored to utilize big data, internet, IOT, new media, and artificial intelligence. The software and hardware of earthquake information services will be developed for the different users including the government officials, the public, and business persons through the personalized and refined service, and interaction service of different scenarios.

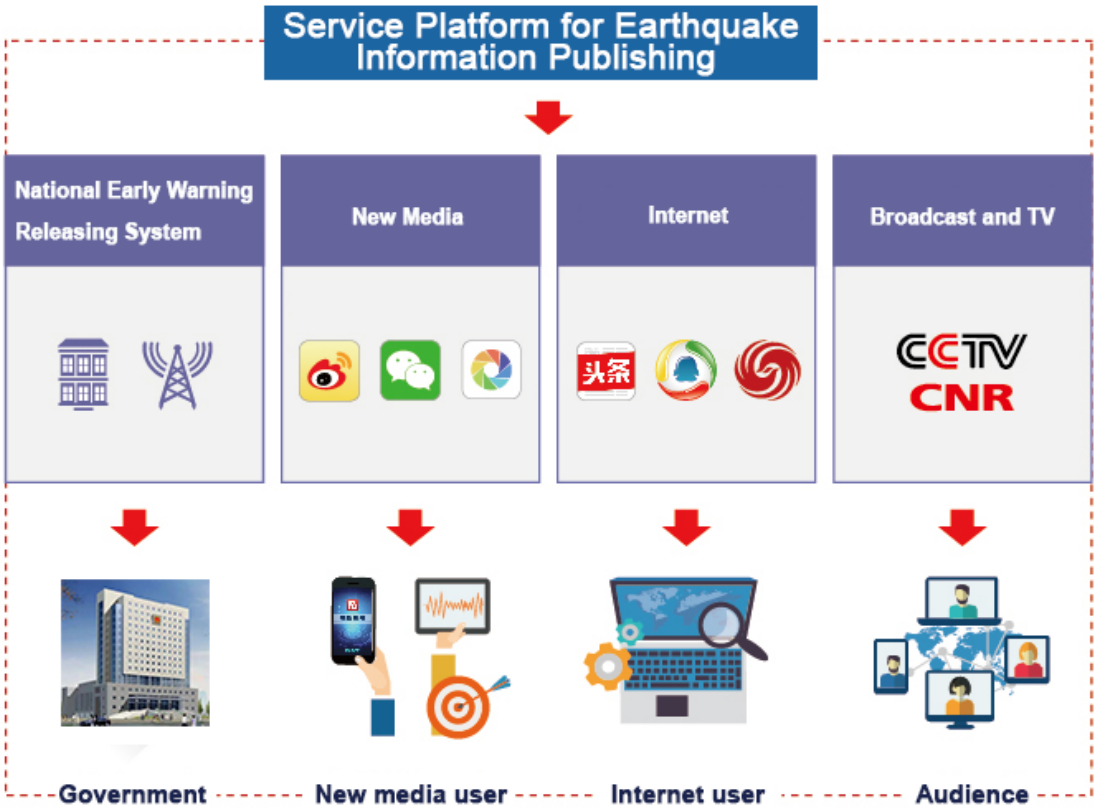

Fig 12. Intelligent Service Platform Network for Earthquake Information

3) Refine Processing of Earthquake Information Service Products

In order to more effectively utilize internet and new media, new products of earthquake information services will be developed. Automatic processing and visualization of monitoring products will be conducted. The accuracy, reliability, practicability and handling strategies of earthquake forecasting will be assessed for the mid- and long-term earthquake forecasting. A series of products on seismic hazard maps

will be developed. The setback policy and regulation for active faults will be established, and information query and avoidance on the active faults will be provided. The minute-level earthquake damage scenarios with different scales will be produced by utilizing earthquake intensity rapid report and earthquake early warning systems. Information of rapid assessment of earthquake affected area, rapid acquisition and evaluation of disasters and rapid evaluation of earthquake loss will be provided. The easy-to-accept and understandable public education materials will be created and distributed.

4) Design and Optimization of Earthquake Standard System

A standardized system of earthquake information will be designed for the optimal services. In order to align with international standards and national general standards, the technical standard system for seismological observation instruments, data, transition, storage, products, and services will be established and improved to form the seismic standard system and project database. The regulation, standard and measures of data source opening, management and protection will be issued.

3. Expected Targets

1) Goal 2020

By 2020, the center for earthquake big data with standard administration, reasonable logic, easy to access and share, will be established to promote the development of earthquake science and related fields; a cloud-based platform for earthquake information service will be established to provide the smart services of seismic information; and an earthquake standard system and framework will be established.

2) Goal 2025

By 2025, a relatively completed earthquake standard system will be established; the data resourcing, cloud operating, and smart service will be implemented to provide the earthquake information service; seismic observation data will be reliably shared in real-time; the cloud-based platform for earthquake information service will be established

to provide variety of information products; the accurate earthquake events and post-event damages and losses information will issued timely; the products of earthquake forecasting and seismic risk information will be standardized; and the earthquake science will be widely covered by the modern media and easily accepted by the public. The public awareness of earthquake prevention and mitigation will be greatly enhanced.