**The Objectives of and Current Progress in Enhanced Capacity Building of TSOs on Nuclear and Radiation Safety in China**

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**Abstract:** TSOs have been playing very important roles during the development of nuclear energy and nuclear technology utilization in China. They face many new challenges and requirements on capacity building after the Fukushima nuclear accident. This paper describes TSOs’ value, functions, capability requirements and general situation, introduces the objectives of TSO capacity building in China as well as current achievements and progress and the construction of China’s National Research and Development Base on Nuclear and Radiation Safety.

**Key Words:** Technical and Scientific Support Organization, Nuclear and Radiation Safety, Capacity Building, National Research and Development Base

**1. Foreword**

The Chinese government has always valued the peaceful utilization of nuclear energy and nuclear technology and paid high attention to nuclear and radiation safety. With decades of steady development, China has formed quite complete nuclear industrial system. Nuclear energy plays a vital role in optimizing energy mix, safeguarding energy security, promoting energy conservation and emission reduction andaddressing climate change. Nuclear technologies are widely used in industrial, agricultural, defense, medical and scientific research fields, giving a strong boost to social and economic development.

To date, there are 20 nuclear power units in operation in China, 28 units under construction, 19 in-service civil research reactors and critical devices, 20 nuclear fuel cycle facilities, 35 uranium mines and over 60,000 organizations utilizing nuclear technologies.Good recordhas been maintained in term of operation safety and construction quality of nuclear facilities and whole process control is practiced on nuclear materials and radiation sources. The level of safety management continues to improve. No nuclear accidents above INES 2 have ever happened and the occurrence of radiation accidents caused by radiation sources is declining year on year. Nuclear safety supervision has incorporated all aspects of the nuclear safetyequipment, ranging from design, manufacturing, installation and nondestructive testing, leading to constantimprovement of equipment quality and reliability.

Meanwhile, China has gradually strengthened preventionand control of radioactive pollution. Decommissioning of old nuclear facilities and disposal of radioactive waste left behind by history also progress steadily. Decommissioning of many miniature neutron source reactors and radiochemical laboratories have completed. Two disposal facilities for middle and low level radioactive waste have been built and put into operation. Another disposal site for middle and low level radioactive waste is now under construction and the building of national storage for spent radioactive sources and temporary depositories for radioactive waste in all provinces (autonomous regions and municipalities) has basically completed. The national radiation environment is good and the radiation level is maintained within the natural background level. The average radiation dose of professionals is far below national limit.

Nuclear energy is the most promising as well as the most challengingenergy source in 21st century, particularly after the Fukushima nuclear accident. The new situationand challenges facing global nuclear safety put increased and higher demands on technical and scientific support organizations (TSOs) for capacity building.

**2. Value and Functions of TSOs**

China’s achievement and progress in the utilization of nuclear energy and nuclear technology are closely connected with TSOs. The value and functions of TSOs are as follows.

* They carry out basic and prospective study and testing, develop high tech technologies and products, promote the translation, extension and application of scientific research results and lay a solid foundation for technology innovation and advance;
* They provide technical and expert support for macro decision making of government, assist nuclear safety supervision departments to perform their duties in an independent, objective, equitable and effective manner and ensure the nuclear and radiation safety of nuclear facilities and nuclear activities.
* Theyprovide life-time and all-rounded technical support and service for nuclear facility operators, meet related requirement of nuclear safety regulations and fully reach and continue to improve the safety, reliability and cost-effectiveness of nuclear facilities/activities.
* They consolidate advantageous resources of the industry and gradually create a professional, international and complementary technical support team. They also carry out academic degree education and on-the-job training and establishimportant think tank, technical reserve and talent pool.

Through decades of development, China’s nuclear energy industry has gradually fostered a professional and specialized technical service market, making TSOs an indispensable part of the industrial chain. The professionalism and specialization of TSOs is conducive to rational distribution and use of advantageous resources, cultivating a professional technical service team with advanced technologyand mature skills. It is also helpful to the digestion and absorption of new technologies, thus promoting the localization of nuclear energy. TSOs will facilitate full exchanges and sharing of personnel, technology, information and experience, reduce operational cost and technical risk of nuclear facilities and improve the safety, reliability and cost-effectiveness of nuclear power industry.

Currently, the nuclear industry development agency, nuclear safety supervision agency and the four major nuclear power corporations of China’s nuclear industry all have technical support affiliates. And there are also a large number of research institutes engaged in research and development of technology and products related with nuclear and radiation safety, personnel education and training, technical consulting and services. The business fields of these TSOs cover the whole life cycle of nuclear facilities, including location, design, manufacturing, installation, operation and decommissioning as well as other activities concerning application of nuclear technologies.

According to industry division and market demand, TSOs, within their respective areas of strength, continue to carry out basic research, study and follow the latest technological developments in the field of international nuclear energy, and provide data support and expert advice for decision making and improvement of nuclear power plants. Through the introduction and independent development of technologies, they also make it possible for the operators of domestic nuclear facilities and activities to quickly share the results achieved by technological advances of the industry as well as maintain and continually improve their safe operation performance.

The main activities carried out by TSOs include:

* Technical support for the review and supervision of nuclear and radiation safety, emergency response and evaluation, research on regulatory policies and regulations, scientific research on nuclear and radiation safety, technical consulting and information services;
* Scientific research and experiment on nuclear physics, nuclear chemistry and radiochemistry, nuclear electronics &detection technology, isotope technology, radiation protection technology, and radioactivity measurement;
* Reactor engineering design and experimental research, the research, design and development of nuclear equipment, the research on reactor fuels and materials, construction project management, and engineering consulting and construction supervision for nuclear facilities;
* Research and application development of operation and maintenance technology fornuclear facilities, safety assessment of nuclear facilities and experience feedback, quality assurance and supervision of nuclear facilities, and technical support for nuclear emergencies;
* Scientific research and technological developmentin such fields as radiation measurement, radiation dosimetry, occupational health and disease prevention, radiobiology, radiation medicine, environmental protection, the treatment of radioactive wastewater, waste gases and solid wastes, and nuclear technology application;
* Geological research of uranium deposits, geological prospecting of uranium deposits, regional geological survey, deposit evaluation, hydrogeology and engineering geology, remote sensing geology, radionuclide detection, radioactive environment evaluation, etc.

**3. Objectives of Capability Building** **of TSOsfor Nuclear and Radiation Safety in China**

The Ministry of Environmental Protection/National Nuclear Safety Administration (MEP/NNSA) is an independentregulatoryauthority for nuclear and radiation safety in China, responsible for nuclear and radiation safety supervision and management of civil nuclear facilities and nuclear technology utilization. Since its establishment in 1984, a relatively complete supervision and management system has been formed, with NNSA as the administrative core, six regional nuclear and radiation safety supervision stationslocating in East China,South China, Southwest China, North China, Northeast China and Northwest China as the dominant supervisoryforces, and the Nuclear andRadiation Safety Centre and the Radiation Monitoring Technical Centre as the technical support. Major breakthroughs have been achieved in terms ofthe structure of government agencies and staffing of nuclear and radiation safety supervision, leading to an organizational size of onehundred staff working in the administration office andonethousand in the central government level.

After thirty years of development, MEP / NNSA has made important achievements in the capacity building of nuclear and radiation safety. The government has continued to intensify its efforts onthe capacity building of nuclear and radiation safety supervision, and increased its fiscal investment year by year. We have established a supervisory framework and a regulatory system for nuclear and radiation safety through the continuous study on international experience and the introduction of advanced concepts, methodologies and techniques. By utilizing the resourcesincorporated in domestic and international cooperation, we have continued to strengthen the regulatory agencies, expandour talent team, create new techniques and improve the regulatory system. We have, at a preliminary level, created a set of supervisory systems and mechanisms of nuclear and radiation safety which are suitablefor China’s national conditions and up to international standards. Meanwhile, we have also basically developed complete and supportive competence to supervise and regulate nuclear and radiation safety. These have played an important role in ensuring nuclear and radiation safety.

After the Fukushima nuclear accident, MEP/NNSAdeveloped and issued *The 12th Five-Year Planand the 2020 Vision of Nuclear Safety and Prevention and Control of Radioactive Pollution*. By meshing the resultsof comprehensive safety inspection and daily safety evaluationof nuclear facilities, carrying out in-depth analysis of the current situation facing the nuclear safety work and existing weak links, as well as taking the assurance of nuclear safety, environmental safety and public health as the goal, the Plan identifies the guidelines, basic principles and goals of nuclear safety work, and made overall plansfor nine key tasks, five key projects, and eight safeguard measures. Furthermore, by sticking to the core of improving safety in the use of nuclear energy and nuclear technology and accelerating radioactive pollution control, and by relying on the strengthening ofscientific and technological research and the improvement of the capability of emergency response and supervisingnuclear safety, the Plan comprehensively strengthens China’s nuclear safety and radioactive pollution prevention and control.

The *Nuclear Safety Plan* also defines the objectives and requirements for China to enhance the capacity building of TSOs for nuclear and radiation safety. The overall goals, specific objectives and vision, as well as key tasks, key projects and safeguard measures described in the Planinvolve many big research projects, and need the cooperation between nuclear safety regulatory authorities and operators of nuclear facilities. They are also inseparable from TSOs’ broad support and in-depth participation.

With respect to strengtheningthe capacity building of nuclear safety supervision and regulation, specific objectives and key tasks put forward by the*Nuclear Safety Plan* are as follows. We shall develop a technology R&Dbase for the national supervision and regulationof nuclear and radiation safety, provide the necessary research means and technical equipment and form the capabilities of conducting relatively independent and more complete analyses and evaluations of nuclear and radiation safety, calibration calculation and experimental verification. We shall enhance relevant infrastructure todevelop the basic ability to carry out international cooperation, publicity and personneltraining. We shall strengthen the capabilities of on-site supervision and law enforcement of nuclear and radiation safety by providing all the necessarytechnical equipment for inspection and enforcement. We shall strengthen the radiation monitoring capabilities of China, and improve the national systems of radiation environmental quality monitoring, supervisory monitoring of pollution sources and emergency monitoringof radiation environment, so as to have the ability tocompletelyunderstand the national radiation environmental quality, carry out relevant evaluation, and conduct emergency monitoring of radiation environment for emergencyresponse tonuclear accidents.

**4. Practices and Progress of NSC in Technical and Scientific Support Area**

The Chinese Government has integrated and employed existing scientific research resources and major researchprograms, supported the basic capacity building of nuclear safety technology researchinstitutions, allocated special scientific research funds and project funds, and offered supports in respect of nuclear safety improvements, capacity building for emergency supports and nuclear safety regulation, treatment of ambient radioactive pollution, and S&T research and development on nuclear safety, to non-profit scientific research and educational facilities, in order to ensure the successful implementation of *Nuclear Safety Plan*, facilitate S&T advances, and promote continued safety upgrading.

As the leading TSO of NNSA, NSC with MEP/NNSA provides all-dimensional technical support and guarantee for the regulation of nuclear safety, radiation safety, radiation environment protection, and nuclear and radiation accident emergencyresponse of civilian nuclear facilities and nuclear activities in China. NSC is also the technical review center, technicalresearch and development center, information exchange center, and human resources development base with regard to nuclear and radiation safety in China.

NNSA has put forward clear requirements and placed high expectations on the capacity building for nuclear and radiation safety regulation and offered full support with respect to organization, leadership, and resources, so that NSC can provide full support and assistance for competent nuclear safety regulatory department in independent, objective, impartial, effective, and efficient fulfillment of regulatory functions. In particular in recent years, NSC has made breakthroughs in terms of not only improvements of human resources, financial resources, team building, and internal management systems, but also technical equipment and technical capacity building, along with the rapid development of nuclear energy undertaking and the continued enhancement and improvement of national nuclear safety regulatory system.

4.1 Optimizing organizational structure through top-down design

NNSA underwent two major restructuring and expansion in 2008 and 2011 respectively, having itsadministrative functions integrated and optimized. In the meantime, the staffing of NSC has grown fast from over 160 to 600, with fiscal budgetmultiplied. NSC has worked with NNSA and developed a mid-and long-term development plan, straightening out and analyzing its lines of businesses and core capabilities, undertaking top-down design, further compartmentalizingitslines of businesses, and optimizing its organizational structure through reshuffle. Furthermore, NSC has employed high-quality and experienced staff by way of campus publicity, job fair, and human resources introduction to expand the team of cadres and of professionals, and offereddiversified training opportunities and career development channels for them.

So far, NSC has around 500 permanent employees working in 16 business departments and 4 administrative departments, thebusinessline of which involvessix areas, i.e., safety review of civilian nuclear facilities and technical support for supervision on them;safety review of radiation environment and technical support for supervision on it;emergency response and assessment of nuclear accidents and radiation accidents; research on regulatory policies and legislations; scientific research on nuclear and radiation safety; and relevant technical consultancy and information service. Meanwhile, a temporary office has been established in charge of the development of National Research and Development Base for Nuclear and Radiation Safety.

4.2 Improving management systems and carrying forward regulatory culture

To address the challenges brought by fast organizational expansion, NSC has gone all out to facilitate the development of management systems, set down or amended a series of management protocols and department-specific working protocols, and enabled its work to be done more and more by following protocols and standards. NSC has also promoted delicacy management in full scale, established suitable and effective working mechanisms, highly valued the performance assessment of regulatory projects and scientific research programs, improved the forces and quality control for technical supports, and kept raising its soft power.

NSC has upheld and carried forward the fine traditions, safety concepts and regulatory culture of the nuclear safety regulatory system and applied them to work while implementing the management systems. These include the principle of “independency, openness, rule of law, rationality, effectiveness” for nuclear safety regulation, and the work attitude and style of “seriousness, preciseness, skepticism, and prudency”, and giving priority to prevention. Upholding the basic policy of “safety first, and quality foremost”, NSChas regarded the nuclear and radiation safety as the lifeline of nuclear energy and technology utilization, and an integral part of national security. Exercising rigorous regulation is the utmost support to the regulated entities and an effective way to avoid losses and gain economic benefits.

4.3Conducting independent check-up calculation and more thorough review

In accordance with the unified arrangements of NNSA, NSC has facilitated capacity building for independent check-up calculationwith regard tothe configuration and development of soft and hard establishments, development of specialized professionals, the overall management and application of relevantcalculation software, etc., in order to improve the independent check-up calculation capacity, increase the technical elements of safety review, and raise the independency, authority, and effectiveness of the review.

Independency in safety analysis and evaluation and in check-up calculation is the core element of capacity building for NSC. NSC’s lines of business involve reactor core and accident analysis, probabilistic safety assessment (PSA), mechanics calculation, criticality safety, radiationprotection, siting, environmental impact assessment, radioactive consequence assessment and emergency response. The main activities are 1) using a safety analysis software the same as original design to verify the design inputs and analysis model of nuclear power plants in terms of correctness, validate the analysis results in terms of correctness and accuracy, and conduct certain parameter sensitivity analysis; 2) using a safety analysis software different from the original design and adopting practical or best estimation analysis method to conduct independent check-up calculation for design improvement projects on new and in-service nuclear power plants, in order to confirm the safety status and safety margin of those plants.

NSC has owned the basic capacity of independent check-up calculation in respect ofthe reactor physics, thermohydraulics, probabilistic safety, mechanics, radiation protection, and environmental impact assessment. Among others, as one of the review methods, independent check-up calculation has been applied in the safety review of AP1000 and CAP1400.

4.4Strengthening technical equipment and establishing a data platform

The successfulresearch and development of full scope simulator has provided a comprehensive technical platform for NSC to offer training programs to professionals and conduct technical validation and confirmation for nuclear powerplant review; increase the understanding of NSC review professionals on the operation and accident disposal standards and protocols of nuclear power plants; improve their review and verification capacities, and enable the review to be morescientific, independent, and efficient.

NSC has highly valued the application of information technology in nuclear and radiation safety regulation, conducted systematic analysis of and made unified arrangements for the general information platforms of various areas of activities and professional databases, and developedcorresponding management systems in respect of emergency response to nuclear accidents, radiation monitoring, radiation source management, qualification management of specialized professionals, experience feedback from nuclear power plants, and internationalcooperation on nuclear and radiation safety, so that historical data can be preserved in intact in electronic form, the working processes can be optimized and regulated, and relevantdata analysis and demonstration methods and tools can be provided.

For example, the databases in the experience feedback information system for in-service nuclear power plants, which are about operation accidents, performance indicators, trend analysis, follow-up of correctional actions, abnormality evaluation, and managementand follow-up of supervision and inspection results, as well as the function modules on regulatory information, experience feedback, safety status evaluation, and training and communications, may help realize the information sharing across the regulatory system, identify priorities of regulation, improve the effectiveness and efficiency of regulation, and promote the continuous improvement of nuclear power plants.

4.5Consolidating the basis of emergency response to accidents and improving monitoring facilities

NSC has established a relatively complete emergency preparedness system and built an efficient team of emergency preparedness and response. NSC has upgraded and rebuilt the Technical Center of Nuclear and Radiation Accident Emergency Response and the hall of the Emergency Response Headquarters, set up state-of-art facilities and devices such as real-time parameter transmission system of nuclear power plants, nuclear accident prediction and consequence evaluation software, emergency response computer network, and videoconference and large-screen display system, which helped further improve the technical support capacity for emergency response to nuclear and radiation accidents.

In the meantime, the emergency monitoring and commanding capacities have been substantially improved. NSC has procured portable radiation monitoring apparatuses, emergency monitoring vans, and mobile emergency response command vehicles, and set up the satellite telecommunication system. It has also established radiation monitoring laboratory with state-of-art monitoring systems, equipment and apparatuses and devices, carried out the measurement and analysis of the γradiation, total radioactivity, and relevant radioactive nucleus of various environmental media, provided abundant data for MEP’s decision making on radiation safety administration and emergency response, and offered competent technical supports for nuclear and radiation safety regulation. NSC radiation monitoring laboratory has passed the CNAS review and obtained laboratory accreditation certificate.

4.6 Conducting subject research and breaking technical bottlenecks

In addition to routine safety review and supervision assignments, NSCcore business departments also undertake the subject research programs in their respective field, and develop safety standards, technical guidelines, review methods and tools for review and supervision of nuclear safety. Furthermore, NSC has energetically taken part in the application, implementation, and acceptance check of scientific research programs includingnational science and technology major programs, programs funded by National Department Public Benefit Research Foundation for environmental protection and National Natural Science Foundation, andNational Key Scientific Instrument and EquipmentDevelopment Projects, and carried out joint research and development programs with national and international research institutions, further strengthening the overall scientific research capacity.

The research subjects cover NSC’s main lines of business, with the focus on reactor safety, prevention and relief of serious accidents, safety of the sites of nuclear power plants, measures taken by nuclear power plants to prevent and buffer the impact of flying objects, reliability of the quality of nuclear safety equipment, safety of nuclear fuel cycle facilities, safety of nucleartechnology utilization, transportation and physical protection of radioactive substances, nuclear emergency response and anti-terrorism, radiation environmental impact assessment and radiation and irradiation control, radioactive waste treatment, and safety of nuclear safety decommissioning.

A permanent technical team has been built for accident analysis and experience feedback, specialized in the monitoring, screening, analysis and feedback of operation accident and regulatory informationof national and overseasnuclear power plants. Aresearch institution specialized in the nuclear safety policy, law and regulation has been established to follow up the international trends and combining with the practical nationalcircumstances and needs, lay a foundation for making regulatory policies, laws and regulations on nuclear and radiation safety in China, enabling them to both follow international advanced practices and comply with national circumstances.

4.7 Enhancing international cooperation and highly valuing public communications

NSChas provided full supports for the implementation of *Nuclear Safety Convention* and *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, and actively taken part in IAEA activities related to the safety standards formulation, training programs and workshops, and ANSN. NSC has organized or participated in the activities of five task forces through the OECD-NEA Multinational Design Evaluation Programme (MDEP). Moreover,NSC has, throughtechnology introduction, information exchange, technical workshops, cooperative research, training programs, and technical consultancy, conducted cooperation and communications with the regulatory organizations and TSOs of the U.S., France, Russia, Pakistan, Japan, and South Korea, in areas of nuclear safety review and regulation, enactment of safety standards for new reactors, construction, commissioning and operation of nuclear power generating units, review and supervision of nuclear safety equipment, nuclear fuel cycle and spent fuel reprocessing, radioactive waste management, emergent notification of and response to nuclear accidents, and radiation dose monitoring.

Through the above said activities, NSChas get a timely understanding of development trends and practices of international society, learnt advanced technologies and management experience, and employed international resources to enhance the research and development, review, and regulatory capacities in the field of nuclear and radiation safety. Meanwhile, NSC has actively shared information, technologies and experience related to China’s nuclear energy development and safety regulation with its international partners, and offer assistance within its capacities to emerging nuclear power development countries.

NSC has built a permanent publicity team to communicate with the public, monitor and respond to public opinions, and share information and address public participation. It has worked on developing relevant principles, management methods and requirements, employed internet, media, brochures and leaflets, advocated full-scale publicity, insisted on positive guidance, improved the transparency of regulatory information, and engaged in publicity and education more voluntarily and effectively. Moreover, NSC has monitored the public opinions, organized meetings at a proper timing to notify social media on nuclear power safety situations, and guaranteed the public right to know, the right to participate, and the right of supervision.

**5. Development of National Research and Development Base for Nuclear and Radiation Safety**

The construction project onNational Research and Development Base for Nuclear and Radiation Safety, which is seated in Changyang Town of Fangshan District, Beijing and covers around 218 *mu* (14.53 ha.), has been included in China’s *Nuclear Safety Plan*. The project proposal of the Base was adopted by NDRC in February 2013, with total approved construction area of 92,957 m2 and capital construction investment of 748.86 mil. yuan. In February 2014, the project was officially approved by NDRC.

The construction project of the Base comprises of 10 major sub-projects including six scientific research and verification laboratories and four shared supporting facilities, with regard to nuclear facilities, nuclear safety equipment, nuclear technology utilization, associate radioactive mines in uranium (thorium) mines, radioactive wastes, transportation of radioactive substances, electromagnetic radiation devices and electromagnetic radiation regulation, as well as nuclear materials regulation and physical protection. These projects will involve all links of nuclear regulation, including siting, design, construction, commissioning, operation, and decommissioning. The Base is planned to be completed in 2020.

Once completed, the Base will act as three platforms-independent analysis and experiment/testing verification platform, information sharing platform, and communication and training platform, and have the capacity of offering independent, scientific, and impartial supports to formulation of legislations and standards, technical review, emergency response and anti-terrorism, monitoring and supervision, and develop into a core strategic base for nuclear and radiation safety regulation with comprehensive, specialized, incentive, and international characteristics.

The Base may help enhance the research and application of basic, leading, and perspective technologies related to nuclear safety, enhance the capacity building for regulation of nuclear facility and nuclear safety equipment as well as for nuclear safety emergency response, facilitate the human resources training and technical communications in respect of nuclear and radiation safety regulation, enable the regulatory capacity to reach international advanced level, and lay a sound and solid foundation for China’s nuclear energy and technology utilization cause to go global.

During the construction and operation of the Base, NNSA will make full use of and integrate the resources, technologies and experience of China in review, regulation and scientific research of nuclear energy and technology utilization, develop the Base into the technical review center, technical research and development center, information exchange center, international cooperation center, and human resources development center in the field of nuclear and radiation safety, and enhanceChina’s capacities in respect of formulation of nuclear and radiation safety regulations and standards, technical review and verification for nuclear and radiation safety, nuclear and radiation accident emergency response and anti-terrorism, radiation monitoring, nuclear and radiation safety regulation, and international cooperation on nuclear and radiation safety.

**6. Conclusions**

China has made certain progress and achievements in terms of capacity building of TSOs on nuclear and radiation safety, but still has some gaps and faces multiple challenges. We are ready and looking forward to working with the international colleagues, continuing to share knowledge, experience, and technologies related to nuclear and radiation safety, collaborating on scientific and technical research and development, addressing difficulties and problems during nuclear energy development, achievingsynchronizeddevelopment with nuclear energy cause, giving play to the unique value and role of TSOs in providing high-quality technical supports and services, and repaying the whole sector and society with greater value outputs.