INITIATIVES SUPPORTING RESEARCH REACTOR SAFETY IN THE ASIA-PACIFIC REGION

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Abstract

The safe and effective operation and utilisation of research reactors in the Asia-Pacific will assist the region as it grows and develops into the world's powerhouse for economic development in the 21st century. This paper explores the drivers for developments in regional research reactor operation and high-level initiatives in safety for some nations. Detailed examples of safety initiatives for research reactors in some Asia-Pacific nations and challenges for the future in the region are given.

1. INTRODUCTION

The Asia-Pacific region is expanding economically at a rate of around 7% according to the United Nations Economic and Social Commission for Asia and Pacific [1]. The growth in China, India and parts of South East Asia, has built on the economic progress made by Japan, Korea and Taiwan during the 20th and early parts of the 21st centuries. Other regional economies, in countries like Australia, have taken advantage of this growth through close linkages in primary production, supply and service-based industries. The increase in energy demand throughout the region, which is projected to continue, has driven policy in a number of countries in the region toward the adoption of nuclear power. This in turn has increased the requirement for nuclear research reactors as tools for building nuclear capability. Research reactors also provide nuclear-based technologies that enhance economies through various disciplines in scientific research, the provision of radio-isotopes for medicine and industry, and the irradiation of materials to support commercial enterprises.

In the Asia-Pacific region over the past 5 years new research reactors have begun operation in Australia and China, and there are plans both for new research reactors and increasing the capability of existing reactors. As regional research reactors' capability and capacity grows there is a responsibility which is shared by regional operators and regulators of research reactors to assure their government, the public and each other that reactor safety is robust and well managed. The assurance generated from this should increase confidence in the growth of nuclear technology in the region. Consequently, those that operate or regulate research reactors have vital roles to play in an important part of sustainable and environmentally responsible economic growth of the region.

This paper reports on initiatives that support research reactor safety in the Asia-Pacific region. Information has been obtained from open source literature, and directly from some regional organisations. There is evidence of increased regional co-operation and information sharing that should enhance capability and capacity in nuclear technology, supporting strategic and economic objectives. Challenges for the future are highlighted and a brief analysis of the means of addressing these challenges is discussed.

2. THE ASIA-PACIFIC REGION

The Asia-Pacific region is often broadly defined as the part of the world in or near the Western Pacific Ocean. Depending on the context, it can include countries all around the Pacific Rim as well as western Asian countries extending into the Middle East. While the term is somewhat imprecise it is generally accepted that the region is centred on South-East Asia. The region's politics and economics are diverse, but in terms of regional development the Asia-Pacific countries are mostly emerging markets experiencing rapid growth.

Fig. 1. The Asia-Pacific region.

According to the Asian Development Bank [2] three of the world's top five economies are in Asia. As the middle-class of those countries grows, production and services will need to expand to meet demand. http://hivaidsclearinghouse.unesco.org/no-cache/clearinghouse-services/news/single-view.html?tx_ttnews%5Btt_news%5D=2016Almost half the total energy in the region is now produced by the People's Republic of China, whose energy production has been growing at an annual rate of 8% since 2000. Measured by energy use per unit of GDP, most Asian economies are becoming more energy-efficient, but coal and gas generation remain the major sources of energy production. As economies and wealth grow, those markets will require new or improved health care services, industrial products, and scientific capabilities. Research reactors will be able to play a role in supporting these increasing requirements.

2.1. Research reactors and their utilization in the Asia-Pacific

According to the IAEA Research Reactor database [3] there are 50 operating, 13 shutdown and 12 decommissioned research reactors in the wider Asia and Pacific region. In terms of safety these reactors have a range of challenges, influenced largely by the design, age and utilisation level. Nuclear and radiological safety is important across the complete facility lifetime, which can be extant for decades. Importantly, this requires the maintenance of human knowledge and expertise, and the provision of appropriate systems and tools which support the human function are also necessary to support safety.

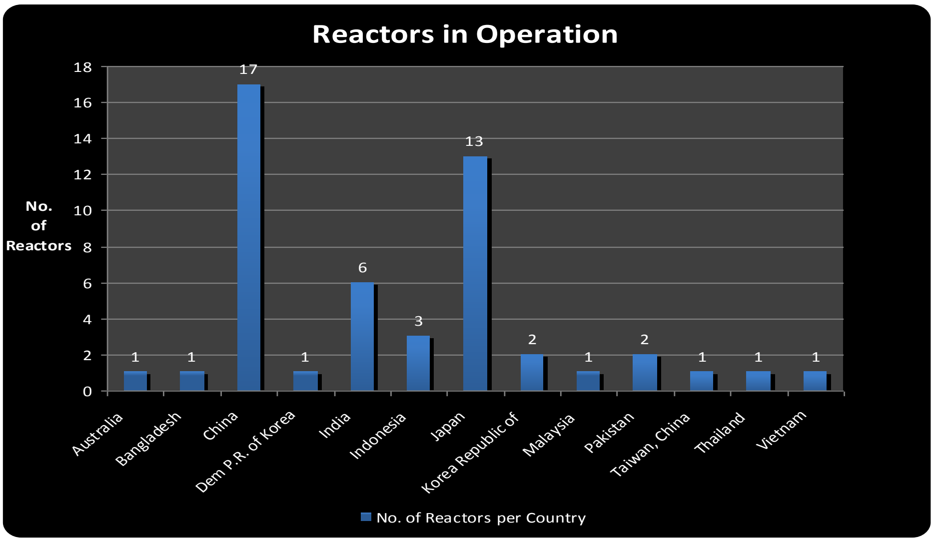

Fig. 2. Operating research reactors by country in the wider Asia-Pacific region.

The IAEA Research Reactor Database shows that 19 research reactors from the region are used to produce radio-isotopes, 11 undertake neutron scattering, 18 conduct neutron radiography, 13 undertake neutron activation analysis, 8 perform irradiations for transmutation doping of silicon, 30 are used to perform materials or fuels irradiations, and 30 conduct some amount of teaching and training. The utilisation of research reactors presents further safety issues in terms of operation, maintenance, and external user interactions.

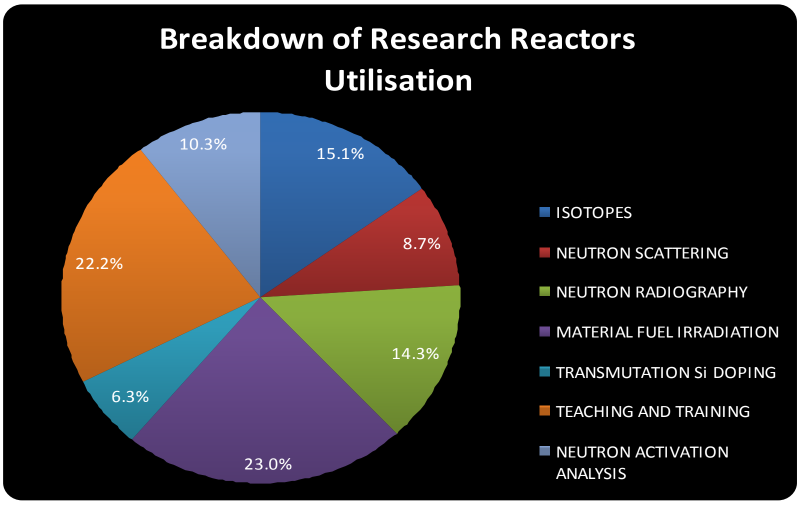

Fig. 3. Proportion of utilization type for operating research reactors in the wider Asia-Pacific region.

2.2. Building capacity in nuclear power

Traditionally, countries used research reactors as a logical step toward developing nuclear power. For example, France applied this strategy and research reactors are still used as a supplement for maintaining capability in nuclear power by utilising them as training tools for nuclear engineers. Research reactors are also used as test-beds for the development of systems that support nuclear power plant technology.

In the Asia-Pacific region several countries have recently made policy decisions to develop nuclear power [4]. In February 2006 the Vietnamese government announced that a 2000 MWe nuclear power plant should be on line by 2020. A nuclear power development plan approved in August 2007 raised the target to a total of 8000 MWe nuclear by 2025. In 2008 a general law on nuclear energy was passed and a comprehensive legal and regulatory framework is currently under development.

In Indonesia three research reactors are operated by BATAN, with the 30 MW reactor at the Serpong Nuclear Facility which has been operating since 1987, originally being intended to support the introduction of nuclear power to the country. More recently the IAEA has been reviewing the safety aspects of nuclear power plant proposals, with Indonesia's Nuclear Technology Supervisory Agency.

In June 2007 the Thailand cabinet established a Nuclear Power Program Development Office which is supervising the Electricity Generating Authority of Thailand’s nuclear build project. Construction of the first NPP unit is proposed to commence in 2014. Thailand has an operating 2MW TRIGA research reactor.

In January 2011 the Malaysia Nuclear Power Corporation was tasked to lead the implementation of nuclear power plants in Malaysia by 2023, subject to a decision scheduled for 2013. The Malaysian Nuclear Agency operates a 2 MW TRIGA research reactor.

China is constructing 26 nuclear power plants, adding to the fleet of 14 operating plants. Those under construction include the world's first Westinghouse AP1000 units, but with most capacity under construction being the locally designed CPR-1000. China operates 17 [3] research reactors (this includes critical facilities) ranging from low power MNSR type reactors to a materials and fuel testing reactor (HFETR) with a power of 125MW. In July 2010 the China Experimental Fast Reactor (CEFR) which is a sodium cooled 65 MW(th) prototype fast reactor achieved first criticality. CEFR will provide China with design, construction and operating experience for fast reactor technology.

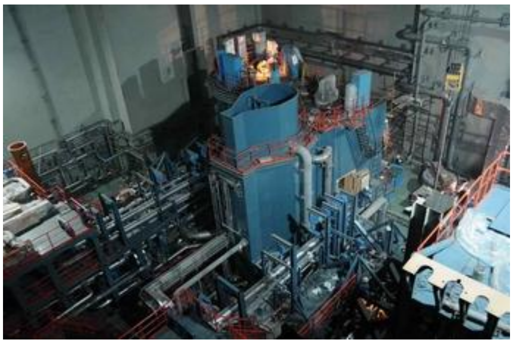

Fig. 4. The China Experimental Fast Reactor operated by China Institute of Atomic Energy, which went critical for the first time in July 2010. (Picture courtesy of CIAE).

Korea has successfully deployed nuclear power plants which operate at very high capacity factors, and have plans to bring a further seven reactors into operation by 2016. The APR-1400 designs have evolved from a US design which has US NRC design certification, and are known as the Korean Next-Generation Reactor. Four further APR-1400 units are planned, and the design has been sold to the United Arab Emirates. Korea is now a supplier of both nuclear power plants and research reactors to Middle East countries, with the successful tendering bid for the Jordan research reactor project.

2.2. Capacity and capability in nuclear science and technology

Research reactors are useful facilities to perform a range of functions in nuclear science and technology, from supply of radio-isotopes for health, neutrons beams to investigate the structure of matter, irradiation of materials for commercial purposes and to support materials development. As more function and capability is added to a reactor design there is an associated increase in complexity, which in turn increases design requirements and which can propagate into challenges in nuclear and radiation safety. For example, irradiation of targets destined for processing into radioisotopes for radio-pharmaceuticals, require special considerations for safety of personnel during transportation and processing of the irradiated material, and treatment of radioactive waste. Some research reactors in the Asia-Pacific region are high power, multi-purpose reactors that need to conform to strict design standards to meet the expectations of regulators and the international community. These reactors include HANARO (Korea), CARR (China) and OPAL (Australia). Older research reactors in the region may be tasked to undertake new functions and/or increased utilisation. With these additional operational requirements, comes an associated safety imperative to plan well for the new functions, test appropriately, monitor progress and maintain new systems. The management of ageing of plant and systems should be a central component to the maintenance strategy both for good safety practice and to financially protect the asset.

2.3. High level safety initiatives

Table 1 shows the operating and regulating organisations for various countries from the broader Asia-Pacific region, and high level safety initiatives for those countries research reactors. Three of the key drivers for the high-level safety initiatives in the Asia-Pacific region are the move to nuclear power, international safety standards and reactor utilisation.

TABLE 1: HIGH LEVEL SAFETY INITIATIVES

Country	High Level Safety Initiative
Australia ANSTO (Operator) ARPANSA (Regulator)	ARPANSA incorporate the principle of international best-practice in nuclear and radiation safety into their regulatory principles. This practice led to the imposition of a licence condition in 2006 on the OPAL research reactor, requiring that Periodic Safety Reviews be undertaken by ANSTO as a condition of reactor operation.
Bangladesh BAEC (Operator) BAEC (Regulator)	The Bangladesh Government has recently instituted a process to establish an independent Regulatory body. A Parliamentary Act, titled "Bangladesh Atomic Energy Regulatory Act-2011" has been finalized in consultation with the IAEA and relevant stakeholders, and is expected to be enacted soon. In 2011 an Intergovernmental Agreement was signed with the Russian Federation for the supply of two VVER NPPs (each 1000 MWe).
China CNNC, CIAE (Operators) CAEA (Regulator)	In 2010 an agreement was reached between CIAE and Argonne National Laboratory (USA) to co-operate on the conversion of MNSR reactors to LEU fuel.
India Various Research Centres under DAE (Operators) AERB (Regulator)	Following the Fukushima accidents the Government have moved to formally separate the AERB from the Department of Atomic Energy. A Bill has been tabled in Parliament and is currently being considered through the committee process.
Indonesia BATAN (Operator) BAPETEN (Regulator)	BAPETEN has released a comprehensive approach to ageing management for research reactors and is incorporating ageing reviews into the re-licensing process using the mechanism of periodic safety reviews.
Japan JAEA and various universities (Operators) MEXT – NSA, (Regulator)	Stress tests have been introduced for Japanese research reactors following the Fukushima Daiichi NPP accidents. These analyses are ongoing.
Korea	KAERI is developing ANSIM (Advanced Nuclear Safety Information Management

KAERI (Operator) KINS (Regulator)	system) to support management and retain staff knowledge in a systematic and efficient way. It will collect information from the facility and the people to support business processes and management, and provide statistics and trends on people.
Malaysia MNA (Operator) AELB (Regulator)	The AELB is undertaking a program to strengthen the national nuclear regulatory infrastructure in preparation for the introduction of nuclear power. The AELB will also be undertaking the Building Regulatory Competency in Probabilistic Nuclear Safety Analysis project, and will become a member of the Global Nuclear Safety Network.
Thailand TAEC (Operator) OAP (Regulator)	The OAP's Bureau of Radiation Safety Regulation has been set up to perform radiation safety regulation and law enforcement, to carry out inspections, evaluation licensing and coordinating of matters related to radiation safety. They also coordinate with other organisations in Thailand and abroad on radiation emergency preparedness.
Vietnam VAEI (Operator) VARANS (Regulator)	VARANS has made a significant investment in the development of people and processes over the last 5 years. Technical capability has increased with assessments being made of the Dalat Reactor included a license renewal application, and LEU reactor core conversion.

While these initiatives are nationally based, building capability and strength in safety can be enhanced through the experience of organisations in other member states using bi-lateral arrangements, partnerships, co-operation agreements and collaborations. For example, Vietnam recently signed co-operation agreements with Russia and the Republic of Korea to assist with the accelerated development of nuclear power in Vietnam.

Another important mechanism is regional networking, with two important networks in the Asia-Pacific region being the Asian Nuclear Safety Network (ANSN) and the Forum for Nuclear Co-operation in Asia (FNCA). ANSN [5] is based on the principle that communicating, exchanging, pooling, analysing and sharing existing and new knowledge in the field of nuclear safety is an essential tool to facilitate sustainable nuclear safety activities. The major objective of the network is to provide an instrument for establishing sustainable and autonomous national and regional nuclear safety activities through the best use of the shared information and discussions in the cyber communities provided by the network. Topical groups exist in legal and government infrastructure, research reactor safety, nuclear power plant safety, emergency preparedness and response, waste management, and education and training. While the FNCA [6] has a wider scope than ANSN, safety is also a major component in its framework, with information exchange and co-operation occurring in the following fields: (1) Radiation Utilization Development (Industrial Utilization/Environmental Utilization, and Healthcare Utilization), (2) Research Reactor Utilization Development, (3) Nuclear Safety Strengthening, and (4) Nuclear Infrastructure Strengthening.

Finally the Research Reactor Code of Conduct [7] provides a basis for member states to aim toward best-practice in nuclear and radiation safety. Self-assessments against the code, as requested for participants at the Convention on Nuclear Safety, can give a useful overview of conformance against that practice.

3. CASE STUDIES

The following case studies provide programmatic information on safety initiatives for selected countries from the Asia-Pacific region.

3.1. Vietnam

At the Dalat research reactor the following improvements have been undertaken:

— Radiation protection: A multichannel area monitoring system has been installed and is in use in 12 different locations in the reactor area, with connections to the central control logic system located in the control room;

- Waste management: A liquid waste evaporator system has been installed in order to minimise the amount of cementation drums required to be processed each year;
- Physical security system: The security system was upgraded in 2008;
- Decommissioning activities: A national research project for setting up a program for decommissioning of the Dalat reactor was carried out during 2009-2011;
- Reactor instrumentation and control system: A project for modification and replacement of the reactor control system (supported by funds from an IAEA TC project and the Vietnam Government) was implemented during 2005-2008;
- Core conversion: Operating procedures were revised in 2010 for the mixed core conversion from HEU (36% enrichment) to LEU (19.75%). The core conversion and the later full LEU conversion was supported by computer code calculations in neutronics, thermal hydraulics and safety analysis. A program for loading LEU fuel in the core for reactor re-startup has been prepared and submitted for approval. The reactor start-up with LEU fuel will be done in November-December 2011;
- Recruitment, training and qualification of personnel: A new process for recruitment, training and qualification of key reactor positions is under preparation and review before approval. Under a cooperation agreement between the Vietnam Atomic Energy Institute (VAEI) and the Japan Atomic Energy Agency (JAEA) a three week training course on Reactor Engineering was conducted.

3.2. China

1) Scope of reactors: China has had a large number of research reactors constructed, ranging from the oldest generation which was built in the 1950's to those from the first decade of the 21st century. There is significant variation in the technical capability, safety systems, and ageing issues of those reactors.

2) Safety management: A comprehensive regime of oversight has been established to ensure reactor safety. The operation and maintenance of all the research reactors are funded and administered by the Bureau of Defence, Science, Technology and Industry, under the Ministry of Industry and Information Technology. The Chinese Atomic Energy Agency (CAEA) interacts with the international nuclear community on the Bureau's behalf.

3) Regulatory framework: The safety of all the research reactors is regulated by the Bureau of Nuclear Safety. Its administrative power includes but is not limited to: (1) Making relevant regulations and technical standards; (2) licensing of nuclear reactors; (3) monitoring and auditing of safety practice; (4) investigation of nuclear safety accidents. In order to fulfil its regulatory function, the Bureau of Nuclear Safety has established six nuclear and radiation safety stations across the country. The personnel in the stations have the responsibility to ensure that the operating organisation complies with, (a) the safety design of the reactor; (b) the approved quality system; (c) license conditions, and audit operators' capability in emergency planning and response. The Bureau of Nuclear Safety has also established The Centre for Nuclear and Radiation Safety as its primary arm of R&D activities and technological support with several branches in different parts of the country.

3.3. Republic of Korea

1) Legal and Regulatory framework: The regulatory body separated from the Ministry Energy Science and Technology (MEST) in October 2011. The regulatory body has a plan for the formulation of specific rules for research reactors, while up to the current time NPP rules have been applied to research reactors mutatis mutandis. KAERI is voluntarily developing a Safety Performance Index for the HANARO reactor. This initiative will be introduced at the current

IAEA conference.

2) Emergency preparedness: In response to the Fukushima accident, KAERI will prepare a Severe Accident Manual for the HANARO reactor based on emergency response from multiple events.

3) Ageing management: KAERI has commenced work for an ageing management program at HANARO. The regulatory body and KAERI are discussing the formulation of a Periodic Safety Review system for research reactors in Korea.

4) Safety culture: KAERI has been undertaking a variety of activities to promote safety culture, including regular seminars and peer reviews. Safety culture surveys have been carried out every two years since 2006 to measure the level of improvement.

5) External events: After Fukushima, the regulatory body reviewed and inspected the HANARO facility and associated documentation, including procedures and safety assessments. A reevaluation of flooding effects under extreme weather condition and a stress test of the reactor building and stack was ordered. KAERI will complete the reevaluation in 2012.

3.4. India

1) Scope of reactors: The Indian research reactor program ranges from the high power 100 MW reactor Dhruva to small pool type reactors, with over 150 years of accumulated operating experience. Safety enhancements at the Bhabha Atomic Research Centre Trombay will be presented in the paper by Mr. C.G. Karhadkar.

2) Safety Reviews: Periodic Safety Reviews conducted at 10 yearly intervals are done as part of the internal review process. National and international operational experience is also systematically reviewed.

3) Ageing Management: Systematic ageing studies were undertaken at the 40 MW Cirus research reactor and the subsequent refurbishments assisted with high availability operation for a further 10 years until the reactor was shut down in December 2010.

4) In-Service Inspection: A program was developed for Dhruva in line with the practice followed at NPPs.

5) Change Management: A well evolved system of change management in research reactors is in practice.

3.5. Australia

1) Periodic Safety Review: The first PSR report for the 20MW OPAL research reactor is in the final stages of review and is due to be submitted to the regulator by the end of November 2011. The review was undertaken generally in accordance with the guidance provided by IAEA Safety Standards Series No. NS-G-2.10, Periodic Safety Review of Nuclear Power Plants [8]. The PSR was subject to independent review by an international peer review team.
Fuel fault and recovery program: Following a fault with reactor fuel in 2007, a fuel re-design and restart program was instituted and the reactor gained approval to restart with a modified fuel design in May 2008. OPAL has operated with high availability levels for the past three calendar years.

2) Asset Management: A modern engineering asset management program commenced in 2010, which uses an industrial methodology for best-practice high reliability organisations with components in: plant maintenance & surveillance; condition monitoring & materials surveillance, including systems to provide reliable predictions of plant remnant life; spare parts and logistics management; component replacements & renewals; obsolescence management; other specific programs identified in the asset management strategy including ageing management

3) Decommissioning: In 2010 ANSTO successfully completed the decommissioning of the 100kW MOATA research reactor. The project won a national award as a model engineering project.

4) Co-operation agreements: ANSTO collaborates with many partners, but two relationships that directly affect the research reactor are the formal co-operation agreement between OPAL, SAFARI1 (South Africa) and HFR (The Netherlands), and the staff exchanges with CEA (France). While these programs are very different in their nature the benefits to the operating organisation are manifest in improvement in practices and development of personnel.

4. CHALLENGES AND THE FUTURE

1) Safety: The worthy goal of achieving "best-practice" in nuclear and radiation safety needs to be tempered by the recognition that research reactors and the community is diverse. That diversity provides strengths, such as the range of applications that are generated from research reactors and weaknesses, such as the level of safety. The achievement of good practice is a journey of improvement that must be realistic in its objectives, have key measurable indicators for performance and outcomes that are tangible. Used correctly, small and large scale safety events can be used as focal points to assist in that improvement. The Fukushima accidents have had a world-wide effect but the regional consequences are particularly important because of the nuclear power developments progressing in the region. The challenge for research reactor safety will be to adapt to the international consensus in safety guidance that develops from the analyses post-Fukushima.

2) Ageing Management: The well recognised challenge of ageing will be amplified, as utilisation levels of existing reactors increases and as new reactors come on line. The resources and systems required to properly implement effective asset management and ageing management are being developed and implemented in some nations, and the sharing of those experiences will be vital for research reactors in the Asia-Pacific.

3) Design Improvements: As reactors age and missions change a robust system for engineering modifications and design improvements will be required. The challenge will be for existing reactors to meet standards and expectations that will become more rigorous and demanding.

4) The development of people: As nuclear capacity and capability grows there will be pressure on educational and nuclear institutions to develop effective programs for the development of people in nuclear.

5) The Life Cycle: Recognition that safety and protection of the environment is necessary well after research reactor operation ceases is required. The challenge will be the adoption of long-term planning and financing to support the management of radioactive wastes into the future.

5. CONCLUSIONS

The Asia-Pacific region is central to the most dynamic growth region on the planet. As the economies grow and nuclear grows it will be incumbent on countries in the region to use nuclear technology for the benefit of their people. The safety challenges will be significant particularly through the magnifying lens of the events at Fukushima and the requirements of safety that this has imposed. The Research Reactor code of conduct can be used as a guide to achieving excellent practice, but the road to good practice in safety will depend ultimately on the adoption of transparent processes that rely on co-operation and continuous improvement in safety culture and practical improvements in engineering. Research reactors will play a vital role in nuclear science and technology use and support the wider use of nuclear technology in the region. Effective co-operation and collaboration will help assure their safety.

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