





एचबीएसटी मानपत्र

नाभिकीय विज्ञान एवं प्रौद्योगिकी में उत्कृष्टता के लिए

HBST Maanpatra

for excellence in science, engineering & technology





Mr. B. N. Rath

नाभिकीय नाभिकीय ईंधनों के पश्च-किरणन एवं नाभिकीय घटकों के विश्लेषण में योगदान

Contributions to Post irradiation of nuclear fuels, analysis of nuclear components

यह मान-पत्र श्री बी. एन. रथ की नाभिकीय ईंधनों के पश्च-किरणन परीक्षण, दा.भा.पा.रि. (पीएचडब्ल्यूआर) दाब नलिकाओं, एवं बाह्य-कोर संरचनात्मक नाभिकीय घटकों के विफलता विश्लेषण सहित अन्य क्षेत्रों में उनके उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है।

The Maanpatra recognises notable achievements of Mr. B.N. Rath in the Post Irradiation Examination of nuclear fuels, PHWR pressure tubes, and failure analysis of out-of-core structural nuclear components among others.

Mr. B. N. Rath, a metallurgist from 46th batch of OCES programme of the BARC Training School, made notable contributions to post irradiation examination (PIE) of nuclear fuel and pressure tubes from pressurised heavy water reactors (PHWRs). Through non-destructive examination, fractography and microstructural characterization, he successfully established the root cause of failure of pressure tubes of Madras Atomic Power Station (MAPS) and provided deep insight on the healthiness of other pressure tubes in the reactor core by meticulously correlating in-service inspection data with PIE findings. His comprehensive investigations during PIE of pressure tubes from Tarapur Atomic Power Station (TAPS) helped in meeting the regulatory requirements for continued operation of TAPS Unit-3&4. Another significant work carried out by Mr. Rath had been the PIE of research reactor Apsara-U fuel sub-assembly and dispersion fuel being developed for compact light water reactors. He carried out extensive investigations involving non-destructive examination, metrology, gamma scanning and microstructure characterization, which provided vital insight on performance of fuel during irradiation. Through variety of destructive and non-destructive tests, Mr. Rath successfully carried out failure analysis of large number of pressure boundary components from nuclear plants. Mr. Rath validated advanced phased array ultrasonic technique for detection and depth sizing of intergranular stress corrosion cracks in recirculation line of TAPS Unit-1&2, which was crucial in taking decision on replacement of pipelines for long term operation of the reactors.

विरल मृदा धातुओं एवं मिश्रधातुओं के उत्पादन हेतु प्रौद्योगिकियों के निरूपण में योगदान

Contributions to Demonstration of technologies for rare earth metals & alloys production



Dr. D. K. Sahoo

Dr. D. K. Sahoo, a Scientific Officer in the Materials Group, BARC, is actively engaged in advancing indigenous technologies for value addition of rare earth elements (REE), a critical step towards establishing the self-reliant rare earth value chain in the country. He made significant contributions towards the development of rare earth metals, alloys and permanent magnets, aligning with department's mandate towards an "Aatmanirbhar Bharat"(self-reliant India).

To start with, he demonstrated the molten salt electrolysis technology to produce RE metals such Lanthanum (La), Cerium (Ce) and Praseodymium (Pr) from domestically available raw materials. The technologies for the production of La and Ce metals were transferred to IREL and subsequently deployed at the Rare Earth and Titanium Theme Park (RETTP), Bhopal for pilot-scale production. He played a key role in the successful deployment at the pilot-plant scale, which laid an important foundation, for further scale-up and transformation of the technology towards commercial-scale production of these metals. One of his notable contributions lies in the development of reduction-diffusion (R-D) technology for the production Sm-Co based alloy powder required for making Sm-Co (1:5) permanent magnet. He has been instrumental in providing technical inputs and facilitating activities in setting up rare earth permanent magnet (REPM) plant at BARC, Visakhapatnam. Recently, he demonstrated the preparation of samarium metal, which marks as a significant achievement aimed at furthering self-sufficiency.

One of the his most notable contributions is the development and demonstration of calciothermic reduction (CTR) based technology for the production of Neodymium (Nd) and Didymium (NdPr) metals using the raw materials available in the country. These technologies were developed under "Aatmanirbhar Bharat" initiatives to manufacture NdFeB magnet in the country. He also demonstrated the processes for producing Dysprosium (Dy) and Terbium (Tb) metal, which are required for producing higher-grade NdFeB magnet. Performance evaluations confirmed that magnets produced using these indigenously developed metals are on par with imported alternatives. Following the success, CTR technology has been successfully implemented at RETTP, Bhopal and a private industry with his incubation support for the production of RE metals required for making NdFeB magnet.

यह मान-पत्र डॉ. डी. के. साहू की विरल मृदा धातुओं, मिश्रधातुओं एवं चुम्बकों के निर्माण हेतु स्वदेशी प्रौद्योगिकियों के विकास में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है, जो कि प्रौद्योगिकीय आत्मनिर्भरता प्राप्त करने में महत्वपूर्ण हैं और भारत में एक पूर्ण विरल मृदा पारिस्थितिक तंत्र स्थापित करने की दिशा में व्यापक प्रयास हैं।

The Maanpatra recognises notable achievements of Dr. D.K. Sahoo in the development of indigenous technologies for preparation of rare earth metals, alloys and magnets, which is key to gaining technological independence in the overall efforts for establishing a complete rare earths ecosystem in India among others.



Dr. Dibakar Goswami

संश्लेषित कार्बनिक रसायन, रसायनचिकित्सीय औषधियों के विकास में योगदान

Contributions to Synthetic organic chemistry, efforts in chemotherapeutic drugs development

यह मान-पत्र डॉ. दिबाकर गोस्वामी की कैंसर के निदान एवं उपचार में व्यापक रूप से प्रयुक्त प्रमुख रेडियोभेषजिक लिगैंडों के स्व-गृह संश्लेषण में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है। इसके अतिरिक्त, उन्होंने कैंसर चिकित्सा की चयनात्मकता एवं प्रभाविकता बढ़ाने के लिए विवेकपूर्ण प्रबंधित आण्विक एवं फ्रेमवर्क-आधारित प्रणालियों की संभावनाओं का भी निरूपण किया है।

The Maanpatra recognises notable achievements of Dr. Dibakar Goswami in the in-house synthesis of key radiopharmaceutical ligands which are widely employed in cancer diagnosis and cancer therapies. Additionally, he demonstrated the potential of rationally engineered molecular and framework-based systems to enhance the selectivity and effectiveness of cancer therapeutics.

Dr. Dibakar Goswami, a Scientific Officer in BioScience Group, BARC was conferred with the prestigious "Homi Bhabha Science and Technology Maanpatra (HBSTM)-2025" by DAE for his contributions in the field of "Synthetic Organic Chemistry."

Dr. Dibakar Goswami joined BARC in 2004 through 47th batch of Training School (Chemistry) after completing his MSc (Chemistry) from The University of Burdwan, West Bengal. He received his PhD (Chemical sciences) from HBNI and subsequently pursued postdoctoral research at The University of Sao Paulo, Brazil under "FAPESP Fellowship". His research focuses on targeted ligands for radiopharmaceuticals and chemotherapeutics, along with the development of organic-inorganic hybrid materials for safer and more specific delivery of chemotherapeutic drugs.

In-house synthesis of radiopharmaceutical ligands is of utmost importance in an endeavor to achieve affordable healthcare, and also to promise uninterrupted supply in hospitals. Dr. Goswami has actively contributed in the synthesis of several radiopharmaceutical ligands like $[Cu(MIBI)_4]BF_4$ (for use in myocardial perfusion imaging), mIBG hemisulfate (for use in therapy of neuroblastoma), Tetrofosmin (for use in myocardial imaging), NOTA-bisphosphonate (for use in early diagnosis of bone metastasis), FAPI-2286 (for use in tumor imaging) etc. Radiopharmaceutical kits made using in-house synthesized ligands have benefitted thousands of patients undergoing treatments in multiple hospitals across India. Apart from that, aiming towards separating carrier free ^{90}Y (from a mixture of ^{90}Sr-^{90}Y) for use in radiopharmaceuticals, he synthesized a rigidified dicarboxamide in multigram scale, which showed satisfactory performance when used in a supported liquid membrane developed through an inter-collaboration in BARC. Besides, Dr. Goswami has also been instrumental in developing the indigenous process for the synthesis of the active drug intermediate, o-Tolylbenzonitrile, one of the highest imported drug intermediates in India.

Through his research on targeted chemotherapeutics, he has successfully synthesized novel small-molecule drug conjugates specifically designed for the targeted treatment of neuroblastoma and prostate cancer. Further conceptual advancement was achieved via employing nanosized metal-organic frameworks (MOFs) and hydrogen-bonded organic frameworks (HOFs) as host platforms for the tumor-targeted delivery of chemotherapeutic agents. These studies demonstrated the potential of rationally engineered molecular and framework-based systems to enhance the selectivity and effectiveness of cancer therapeutics.

अभिक्रियाशील एवं दुर्गलनीय धातुओं हेतु गलित लवण विद्युत-अपघट्रिों के विकास में योगदान

Contributions to Development of Molten Salt Electrolysers for Reactive & Refractory Metals



Mr. Gaurav Varshney

Mr. Gaurav Varshney, a chemical engineer, graduated from the 47th OCES batch of the BARC Training School. Since joining the Chemical Engineering Group as a Scientific Officer in 2004, he has devoted over two decades to the design, development and operation of pilot-scale molten salt electrolysers. The Homi Bhabha Science & Technology Maanpatra-2025 has been conferred upon him in recognition of his outstanding contributions towards "Electrolysers for Critical Metal Production."

A major contribution of Mr. Varshney has been his technical leadership in the operational and R&D activities of the metal production facility, where he has played a key role in ensuring the safe, sustained and efficient production of high-purity metals. Through systematic engineering interventions, he reconfigured critical electrolyser design features to enhance productivity, process efficiency and operational reliability. He further optimized the process flowsheet by incorporating recycling of metal values and conversion of legacy stockpiles into usable metal products. This approach not only improved resource utilization but also significantly reduced the operational load on the precursor plant.

He established a pilot-scale electrolyser facility for the production of refractory metals. He led the systematic optimization of electrode configurations and operating parameters to achieve a high-quality metal powder with favourable consolidation characteristics and enhanced downstream recovery. Under his technical leadership, kilogram-scale production of the metal powder was demonstrated and subsequently transformed into solid blades. These blades were successfully tested in the Critical Facility, demonstrating the required performance and reactivity for effective neutron absorption.

In another important technological achievement, Mr. Varshney played a pivotal role in the scale-up of catalytic hydrogenation at the Advanced Crown Ether Synthesis Plant (ACESP). He led the team in achieving a major breakthrough in the indigenous bulk-scale production of strontium-selective crown ether, successfully demonstrating production at 1 kg/batch scale. The specialized solvent serves as an import substitute for the recovery of Strontium-90 from high-level nuclear waste and which has potential applications in Radiomedicine and Radioisotope Thermoelectric Generators (RTGs).

Through innovative engineering and process expertise, Mr. Varshney has contributed significantly to the safe, reliable and highly efficient production of high-purity reactive and refractory metals vital for departmental applications. His work has strengthened indigenous technological capabilities in critical metal production while advancing the development and scale-up of specialized electrochemical and chemical processes.

यह मान-पत्र श्री गौरव वार्ष्णेय की क्रांतिक धातु उत्पादन हेतु विद्युत-अपघटित्र के विकास में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है। व्यवस्थित अभियांत्रिकीय परिवर्तनों के माध्यम से, उन्होंने उत्पादकता, प्रक्रम दक्षता एवं परिचालन विश्वसनीयता में वृद्धि करने हेतु विद्युत-अपघटित्र की क्रांतिक अभिकल्पन विशेषताओं को पुनःविन्यासित करने सहित अन्य कार्यों में महत्वपूर्ण योगदान दिया है।

The Maanpatra recognises notable achievements of Mr. Gaurav Varshney in the development of Electrolysers for Critical Metal Production. Through systematic engineering interventions, he reconfigured critical electrolyser design features to enhance productivity, process efficiency and operational reliability among others.



Dr. Jyoti Prakash

बृहत अनुप्रयोगों हेतु प्रगत कार्बन-आधारित पदार्थों के विकास में योगदान

Contributions to Advanced carbon-based materials development for major applications

यह मान-पत्र डॉ. ज्योति प्रकाश की विविध अनुप्रयोगों विशेषकर भारत की सबसे हल्की बुलेट-प्रूफ जैकेट, भाभा कवच के विकास को संभव बनाने के लिए CNT-संयुक्त UHMWPE मिश्रित परतों के निर्माण के अंतर्गत, नाभिकीय-ग्रेड के ग्रेफाइट, लेपन प्रौद्योगिकी, कार्बन नैनोपदार्थ सहित कार्बन पदार्थ एवं प्रौद्योगिकियों में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है।

The Maanpatra recognises Dr. Jyoti Prakash's notable achievements in carbon materials and technologies, including nuclear-grade graphite, coating technologies, carbon nanomaterials, and composites for diverse applications, notably CNT-incorporated UHMWPE composite layers enabling India's lightest bulletproof jacket, Bhabha Kavach.

Dr. Jyoti Prakash, a Scientific Officer in the Materials Group of BARC, was conferred with the prestigious 'Homi Bhabha Science & Technology Maanpatra (HBSTM) - 2025' by DAE for his outstanding contributions to advanced carbon-based materials development for strategic and societal applications.

Briefly, there is a stringent requirement for indigenous isotropic high-density graphite for the molten salt breeder reactor under development in India, with no reliable external supply chain. To address this critical gap, Dr. Prakash proposed and developed a novel flowsheet utilizing meso-carbon microbeads as a starting material. He successfully demonstrated the lab-scale production of high-density, pure isotropic graphite requiring fewer steps than conventional methods. Furthermore, he achieved low-temperature coating of Silicon Carbide layers on these graphite components using an in-house atmospheric pressure chemical vapor deposition process. By proposing a uniform deposition model based on deposition kinetics and evaluating the adherence and permeability properties as per nuclear ASTM standards, his work provided valuable insights into high-temperature oxidation behavior in actual reactor environments. This indigenous process is currently being scaled up to cater to reactor requirements.

Beyond nuclear materials, Dr. Prakash has pioneered the development of carbon nanomaterials, including carbon nanotubes (CNTs) and graphene. A major strategic milestone was his development of a process for CNT-incorporated UHMWPE composite layers, enabling the fabrication of "Bhabha Kavach," India's lightest bullet-proof jacket. Furthermore, he achieved the large-scale indigenous manufacturing of self-assembled, standalone CNT aerogel electrodes. Utilizing these novel architectures, he developed rapid, ultra-sensitive, and robust sensors capable of detecting hazardous gases, sulfides, and VOC biomarkers at parts-per-billion (ppb) levels.

Dr. Prakash's scientific excellence has been widely acknowledged globally and nationally. He is a recipient of the prestigious Fulbright-Nehru Post-doctoral Fellowship (2017), the DAE Young Applied Scientist Award (2013), the DAE Group Achievement Award (2019) for delivering Bhabha Kavach, and the Dr. R. L. Thakur Memorial Award (2016). Recently, he was honored with the B.D. Bangur Award (2026) and the Birla Carbon Best Innovation Award (2026). Dr. Prakash is an elected Young Associate of the Maharashtra Academy of Sciences, an Associate of the Royal Society of Chemistry, and a life member of multiple esteemed professional societies.

विकिरण आपात-स्थितियों एवं सटीक औषधि हेतु जैव-मात्रामापी को उन्नत बनाने में योगदान

Contributions to Advancing Biodosimetry for Radiation Emergencies and Precision Medicine



Dr. Rajesh Kumar Chaurasia

Dr. Rajesh Kumar Chaurasia, a Scientific Officer in the Health, Safety and Environment Group, BARC was conferred with the prestigious "Homi Bhabha Science & Technology Maanpatra (HBSTM), 2025" by DAE for his outstanding contribution in the field of "Advancing Biodosimetry Tools and Their Applications in Radiation Emergency Response and Precision Medicine".

Dr. Chaurasia joined BARC in 2012 through the 55th batch of Training School (Bioscience) after completing his M. Tech. (Biotechnology) from IIT Guwahati. He received his PhD (Life Sciences) from HBNI. His research interests span advancing biodosimetry techniques, ranging from rapid emergency dose assessment to long-term retrospective dose estimation, coupled with cytogenetic investigations of rare genetic syndromes and radiation sensitivity in paediatric patients.

Dr. Chaurasia has strengthened national capabilities in radiation dose assessment by developing and validating three major biodosimetry tools, along with their reference calibration curves: a rapid emergency biodosimetry tool that enables dose assessment much faster than conventional methods, supporting effective emergency preparedness; a retrospective dosimetry tool, enabling reliable dose estimation for exposures ranging from decades to lifetime; and an mBAND-FISH-based approach that discriminates between low- and high-LET radiation exposures.

He led the establishment of India's first biodosimetry network (IN-BioDoS), integrating seven laboratories nationwide to strengthen radiological emergency preparedness. He also led the country's first inter-laboratory comparison to set quality assurance standards in biodosimetry. He has collaborated extensively on biodosimetry and its clinical applications with several institutions across India, including, SRU (Chennai), UPES (Dehradun), NITTE University (Mangalore), ACTREC-TMH (Navi Mumbai), ICMR-NIIH (Mumbai), and IGCAR (Kalpakkam).

Dr. Chaurasia also developed a patented novel formulation, Fixative Composition Saline (FCS). It is a single-step formulation that lyses RBCs while preserving WBC nuclear morphology and genomic integrity. FCS remains stable for over a year at ambient temperature, simplifying blood sample handling, transport, and long-term storage, particularly benefiting sample collection in remote areas.

His clinical research has translated cytogenetic and DNA-DSB repair protein analysis into direct patient benefit, by assessing genomic instability and radiosensitivity to guide personalized treatment for children with rare immunodeficiencies, including Wiskott-Aldrich Syndrome, Fanconi Anemia, DOCK8 Deficiency, and LADD Syndrome.

Dr. Chaurasia has represented India on the global stage under the Indo-US Technical Exchange Program at REAC/TS, USA, advancing biodosimetry techniques for high-LET radiation. He also represented India at the 7th Plenary Meeting of the High-Level Group on Low Dose Research (HLG-LDR), organized by the Nuclear Energy Agency (NEA) in France, contributing to global policy coordination on low-dose radiation research. He has mentored master's and Ph.D. scholars from institutions across the country, as well as an international fellow under the ASEAN-India Research and Training Fellowship, strengthening India's leadership in regional biodosimetry capacity-building.

यह मान-पत्र डॉ. राजेश कुमार चौरसिया को भारत के प्रथम जैव-मात्रामिति नेटवर्क (IN-BioDoS) के गठन में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है, जो देशभर में सात प्रयोगशालाओं को एकीकृत करता है और देश के प्रथम अंतर प्रयोगशाला तुलना के माध्यम से गुणवत्ता मानकों को स्थापित करता है। अन्य कार्यों के साथ, उनके इस अध्ययनों से, असाधारण प्रतिरक्षाविहीनता सिंड्रोम से ग्रस्त बच्चों में विकिरण संवेदनशीलता एवं जीनोमिक अस्थिरता के संबंध में नई अंतर्दृष्टि प्राप्त हुई है और वैयक्तिकृत रेडियोथेरेपी हेतु अनुशंसित करता है।

The Maanpatra recognises notable achievements of Dr. Rajesh Kumar Chaurasia in establishment of India's first biodosimetry network (IN-BioDoS) - integrating seven laboratories nationwide and setting quality standards through the country's first inter laboratory comparison. His analyses provided new insight into radiosensitivity and genomic instability in children with rare immunodeficiency syndromes, recommending personalized radiotherapy among others.



Dr. Rubel Chakravarty

रेडियोसमस्थानिकों एवं रेडियोभेषजिकों के विकास हेतु नव प्रौद्योगिकियों में योगदान

Contributions to New technologies for radioisotopes & radiopharmaceuticals development

यह मान-पत्र डॉ. रुबेल चक्रवर्ती को रेडियोआइसोटोप उत्पादन एवं रेडियोभेषजिक के लिए अग्रणी स्वदेशी प्रौद्योगिकियों के विकास में उल्लेखनीय उपलब्धियों को मान्यता प्रदान करता है। उन्होंने प्रयोगशाला-आधारित नवाचारों को कैंसर प्रतिबिंबन एवं लक्षित चिकित्सा के नैदानिक अनुप्रयोगों में रूपांतरित करने में महत्वपूर्ण योगदान दिया है।

The Maanpatra recognises notable achievements of Dr. Rubel Chakravarty encompassing pioneering indigenous technologies for radioisotope production and radiopharmaceutical development, translating laboratory innovations into clinical applications for cancer imaging and targeted therapy.

Dr. Rubel Chakravarty, Scientific Officer in the Radio Chemistry & Isotope Group, BARC and Associate Professor, Homi Bhabha National Institute (HBNI), was conferred the Homi Bhabha Science & Technology Maanpatra (HBSTM) – 2025 for his contributions to the production of medically important radioisotopes and development of radiopharmaceuticals. His research has focused on developing indigenous technologies that take radioisotopes from production and radiochemical separation through radiopharmaceutical formulation and, ultimately, to clinical application.

A significant part of this work has involved the production and radiochemical separation of clinically relevant radioisotopes, including ^{177}Lu, $^{43/44}$Sc, ^{47}Sc, ^{52}Mn, ^{64}Cu, ^{124}I, ^{161}Tb, ^{166}Ho, ^{169}Er, and ^{211}At. In particular, he developed an electrochemical process for the separation of no-carrier-added (NCA) ^{177}Lu from irradiated ^{177}Yb. The NCA ^{177}Lu obtained by this indigenous process was successfully used for preparation of therapeutic radiopharmaceuticals and subsequently administered to cancer patients in clinical practice.

Another important achievement has been the development of reactor-produced ^{64}Cu and its radiochemical separation for preparation of clinical-grade [^{64}Cu]$CuCl_2$. Following regulatory clearance, the radiopharmaceutical was used for PET imaging in clinical studies. His work in radiopharmaceutical chemistry has also resulted in targeted agents such as [^{177}Lu]Lu-DOTA-Trastuzumab-Fab, which progressed to a first-in-human clinical study in breast cancer.

His research has subsequently extended into radio-nanomedicine, combining radionuclides with engineered nanomaterials for localized and targeted cancer therapy. Notably, his intrinsically radiolabeled [^{177}Lu]Lu_2O_3 nanoparticles were taken into a clinical study involving patients with locally advanced breast cancer. This work provided a clinical demonstration of the emerging concept of "nanoscale brachytherapy," using radioactive nanoseeds to deliver localized radiation within the tumour.

The common thread across these efforts is the translation of radioisotope production, radiopharmaceutical chemistry and nanotechnology into patient-oriented applications. Several of these technologies have received regulatory approval and progressed towards clinical use and wider deployment, contributing to indigenous capabilities in nuclear medicine.

साधारण-जल रिएक्टर के पंप हेतु विशेष संहत कैन्ड मोटरों के विकास में योगदान

Contributions to Development of special compact canned motors for pumps of LWR



Mr. Rupendra Singh

Mr. Rupendra Singh, Scientific Officer in the Reactor Projects Group, BARC was conferred with 'Homi Bhabha Science & Technology Maanpatra-2025' by DAE as recognition of his outstanding contributions in the field of "Development of Special Compact Canned Motors for Pumps of Light Water Reactor".

He has significantly contributed in design and development of indigenous compact, silent and high reliability Canned Motors (CM) for Primary Circulating Pump, Shut Down Cooling Pump & Component Cooling Water Pump for Compact Light Water Reactors of critical projects. His work also includes development of state-of-art fabrication and testing equipment for design, development, testing and qualification of the indigenised CMs. Multiple units of these CM Pumps were qualified and deployed in the service.

यह मान-पत्र श्री रुपेन्द्र सिंह को आत्म-निर्भरता की दिशा में राष्ट्रीय नाभिकीय क्षमताओं को सशक्त बनाने के लिए साधारण जल रिएक्टरों हेतु क्रांतिक पंपों के विशेष कैन्ड मोटरों के स्वदेशी विकास एवं परिनियोजन को संभव बनाने में उल्लेखनीय योगदान को मान्यता प्रदान करता है।

The Maanpatra recognises the notable achievements by Mr. Rupendra Singh, which enabled indigenous development and deployment of Special Canned Motors of Critical Pumps for Light Water Reactors to strengthen national nuclear capabilities for self-reliance.