10th NIAS-CISAC WORKSHOP ON

INDIA-U.S. COOPERATION ON GLOBAL SECURITY: TECHNICAL ASPECTS OF CIVILIAN NUCLEAR SECURITY

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SUMMARY REPORT

The 10th NIAS-CISAC workshop on the theme "Technical Aspects of Civilian Nuclear Security" was held in NIAS, Bangalore on 29-31 October 2012. The first ideologue in this series was held way back in 1999 at NIAS that mainly dealt with nuclear weapon issues. Discussion on topics of ballistic missiles, space security, nuclear weapons free world, science and technology to counter terrorism, biological threats and biological security and science cooperation were conducted in subsequent meetings.

The topics discussed during the technical sessions of the current workshop included Civilian Nuclear Security, Securing Nuclear Materials, Technologies and Physical Security of Nuclear Materials, Nuclear Forensics, Security and Human Factor at Civilian Nuclear Facilities, Cyber Security for Civilian Nuclear Materials Security and Systems Approach to Civilian Nuclear Security.

The US team had members drawn from the important nuclear related national laboratories and academia and the Indian speakers for the workshop were largely from the serving and retired senior scientists of the Department of Atomic Energy and academia as shown in Annexure 1.

The basic goals and objectives of this joint workshop were:

- To build mutual understanding of how experts in India and the United States approach issues of civilian nuclear materials management and security;

- To establish contacts among and Indian and US scientists and experts on nuclear materials security in order to explore future areas of cooperation relating to nuclear security issues;

- To identify potential areas of cooperation in scientific and technical fields between the experts and institutions in India and the United States

Given these goals and objectives, NIAS and NAS encouraged open and frank discussion during the workshop. In their opening remarks Dr. Ramamurthy, director NIAS, Dr. Raymond Jeanloz, Professor, University of California Berkeley and Professor Stephen Cohen urged all participants to actively engage in the discussions and seek specific opportunities for further collaborative scientific efforts between two countries.

The first session of the workshop dealt on the theme "Overview of Civilian Nuclear Security: A Systems Approach". Dr. M.R. Srinivasan, Former Chairman, Atomic Energy Commission represented the Indian side and Dr. Robert Kuckuck, Former Director, Lawrence Livermore National Laboratory spoke from the U.S side in this section. Dr. Srinivasan began by drawing attention to the Fukushima accident and the challenges it has posed to the entire nuclear community across the globe. According to him, India too, has had to face domestic activism opposition against the Kudankulam Nuclear Power Plant (NPP) project following the Fukushima accident and much of the domestic opposition is fuelled by incorrect information and there is a need to rectify the situation by educating the local population and thereby addressing their fears. Dr. Srinivasan underlined the importance of nuclear power in satiating India's energy requirements which is critical for India to continue on its growth trajectory. The speaker also pointed to the cheaper costs of setting up Indian power reactors as a result of high indigenisation

vis-à-vis imported nuclear power reactors. Concluding the talk, Dr. Srinivasan pointed to the need to bolster international nuclear cooperation.

Dr Kuckuck began by pointing out that civilian nuclear safety can be seen at the global, domestic and facility operational level. He underlined two principles which drive nuclear security system in facility operations. The first principle is that the material the facility is working on (whether weapons-usable or weapons-grade) must be kept out of the hands of the adversary. The second principle is that no material is absolutely safe; every material is vulnerable to some level of threat. Nuclear security thus is as much a matter or risk management which has to take in to account dynamic factors like quality and quantity of material present in the facility, the security measures in place in the facility, the capabilities an adversary can bring. The speaker underlined the importance of sustaining the nuclear culture while keeping in mind that there cannot be too much security so as to hinder the functioning of the staff at the facility and at the same time not allowing complacency to creep into security related matters.

The second session of the workshop dealt on the theme "Securing Nuclear Materials" with presentation by Prof. R. Rajaraman, Emeritus Professor, JNU, Dr.Ravi Grover, Director, Strategic Planning Group, BARC and Dr. Peter Santi, Scientist, Safeguards Science and Technology Group, LANL. Prof. Rajaraman gave an overview of nuclear materials and their security with a global perspective. He started his talk by clarifying what these materials are, their different categories, estimated stocks in different countries and the urgent need to secure those materials. According to him, until a few years back, the term Nuclear Materials by and large stood for Fissile Materials and consequently, the international community was most concerned about them. But today, the phrase "nuclear materials" has acquired a wider meaning with the increasing interest in civilian nuclear security and safety as well as radiological terrorism. He also highlighted that more than 99% of the stocks of these materials are in weapon countries, with more than half of that in the military sector. That still leaves a considerable amount in the civilian sector. Although the P5 nations possess the overwhelmingly large fraction of FM, there is plenty in absolute quantities in 40 other nations. Just the NNW states possess about 10 tons of HEU, worth about 400 warheads. Even countries which do not possess any FM have to be vigilant that they are not used for transit of FM.

Dr. Ravi Grover stared his talk by referring to a study conducted by DAE with the objective of quantifying the share of nuclear energy in the electricity mix in India in the coming five decades. According to him, the study indicated that total electricity generation in the year 2052 will be about 8000 TWh corresponding to annual per capita generation of 5300 kWh. To achieve this target in his opinion, one has to look at the fuel resource position of India. India has coal deposits, but its oil and gas reserves are quite modest and full potential of renewable energy resources also needs to be exploited, but their potential itself is limited.

According to him since NSG guidelines have made civil nuclear trade possible for India, the DAE has announced plans to set up light water reactors in collaboration with other countries including USA, France and Russia. Strategy prepared for growth of nuclear installed capacity envisages achieving a target of about 60,000 MW by 2030. Pursuit of closed fuel cycle has been an integral part of India's nuclear power policy as it enables to realise the full energy potential of uranium and makes possible to tap energy potential of thorium. He reiterated that this policy will continue even after the opening up of international civil nuclear trade. He summed up by highlighting, India is following a closed fuel cycle approach, has developed necessary technologies for this purpose and reprocessing is followed by reuse of recovered plutonium. No

research reactor is operating on HEU. Adequate steps, including setting up of training facilities are being taken to secure the future. To address the issue of security of nuclear material on a longer term, research and development on proliferation resistant technologies has been ongoing for the past several years.

Dr. Peter A. Santi concentrated in his talk on the theme "The Importance of Nuclear Material Measurements to Nuclear Safeguards, Material Control and Accountability, and Security". In his words, acceptance by the public of the use of Special Nuclear Materials (SNM) is contingent in part of the ability of the nuclear establishment to ensure that the use of these materials will not bring unjustified harm. This requires the establishment of three important principles associated with managing nuclear material within a nuclear facility, such as Safety (material doesn't cause harm to public or workers), Security (preventing material from leaving authorized area) and Safeguards (material is accounted for and under constant control within a facility). While the three areas have different responsibilities associated with managing nuclear material, one area of commonality associated with all three disciplines is the need to detect, identify, and quantify nuclear materials. He also highlighted the measurement terminologies and the importance of NDA measurements over DA measurements. In conclusion he pointed out that high quality nuclear measurements of nuclear materials are necessary for the safety, security, and safeguards associated with a facility and performing high quality nuclear measurements requires that the personnel involved in these measurements receive the appropriate level and type of training.

The third session of the workshop was on "Nuclear Forensics". Dr. V. Venugopal from BARC and Dr. Ian Hutcheon of Glenn Seaborg Institute presented papers on this theme. The ability to track the origin of a nuclear material (where it came from? who was involved in its production?) is critical to nuclear security in the 21st century where weapons-usable plutonium and highly enriched uranium (HEU) is found in 40 countries. According to both presenters, assigning a source to nuclear material is also important in the context of implementing laws regarding radioactive substance disposal. It is this question of attribution that is addressed by nuclear forensics.

A nuclear material can be traced back by identifying the unique signatures it acquires as it goes through its fuel cycle (mining, conversion, enrichment, fabrication, fuel use in reactors, reprocessing and disposal). This provides it with something akin to a 'fingerprint'. Nuclear forensics decodes the 'fingerprint' through:

Scientific signature analyses ⟶ Evaluation of data through comparison with database ⟶ Conclusions/Interpretations/Attributions

Signature analyses collect data on isotopic/trace elemental composition, isotopic/trace elemental abundance, sample morphology, etc. to answer questions such as: whether the sample is natural, nuclear waste or spent reactor fuel, what is the age of the sample, how much processing it has undergone, the type of reactor it may have been used in. However, there is no one signature which can determine the 'fingerprint'; it is only through the intersection of multiple signatures that appropriate attribution confidence can be built. Ian Hutcheon pointed out the need for more understanding of the mechanism that controls signatures.

While India has the analytical tools to carry out high resolution gamma spectroscopy, elemental isotopic analysis, microanalysis and imaging, V. Venugopal emphasized the need for state-of-the-art systems in thermal ionization mass spectrometry (TIMS) and secondary ion mass

spectrometry (SIMS) to expand the range of analysis. According to Dr. Hutcheon on the other hand, the U.S has the capacity to analyze a large range of samples from kilograms to picograms with a high degree of accuracy. An excellent example to illustrate the principles of nuclear forensics analysis in the U.S. is the *Yellow Cake* or UOC (Uranium Ore Concentration) approach.

Dr. Hutcheon calls nuclear forensics an emerging and imperfect science—emerging because it has acquired an international attention only in the last ten years and imperfect because of its reliance on a database of 'fingerprints'. The Session was concluded by summarizing access to technology is important and all stake holders are beginning to realize the need to develop nuclear analysis knowhow, not everyone has equal access to the best global technology. They also called for *international cooperation* to prevent incidence of trafficking of HEU and enriched Plutonium cooperation in the development of cutting-edge science as Nuclear Forensics, still in its nascent stage and can attract the best and the brightest minds if it is connected with cutting-edge science and brought into the mainstream.

Dr. Suresh Babu from BARC represented the Indian side and Dr. Cliff Glantz, from PNNL represented the U.S side in the fourth session on "Cyber Security for Civilian Nuclear Materials Security". Dr Babu considered two aspects of cyber security in nuclear facility in his presentation, viz., Instrumentation & Control (I&C) Security and Facility Network Security (FNS). The speaker covered both the forms of security—physical and information. The different components of the security and their management are covered in brief. The speaker explained the concepts of 'Defense-in-depth' and 'Security life cycle'. After mentioning about the main issues in cyber security, the speaker concluded the talk with the example of Secure Network Access System (SNAS) in BARC.

Dr. Glantz started by briefing the PNNL, its focus, responsibility, and assignments. The speaker also made the house aware about the U.S. Nuclear Regulatory Commission's Cyber Security Rule. The proactive (defense) and reactive (mitigate) components of cyber security was also covered. Then the speaker explained in detail the management, operational and technical aspect of the security. Specifically, he covered operational class of security control in detail. The speaker concluded the talk with a detail discussion on relationship between physical and cyber security.

The two presentations were followed by some interesting discussions. Questions were put to the panel on considering cyber-attacks similar to other attacks on security and hence, the right to retaliate. However, the presenters convinced the house that cyber-attacks need to be treated differently as in case of cyber attacks, the origin of the attack is very difficult to trace. Hence, retaliation is not possible, and if done in a hurry, can be miss-targeted. The discussion in this regard covered many of the recent cyber attacks. Also, there was a question on the recent Mumbai cyber attack, where the attack was carried out during the security system upgrade time. The panel gave the clarification that this attack was made possible due to an information leak. However, the possibility of 24*7 cyber attack cannot be ruled out in similar cases. The discussion also covered the technical side of upgrading cyber security and the role of software language in the same. There was a query on optimal number of layers. The house acknowledged that though with an increase in layer, there is increased security, but this can lead to increased scope for leaks. The last question of the session was whether it is possible to detect the

authenticity of the security update source. To this, one of the presenters replied in affirmative. The session ended with an appreciation note from the chairperson to both the presenters.

The fifth session of the workshop dealt with "Technologies and Physical Security of Nuclear Materials". The presentation made by Dr. Ranajit Kumar, BARC and Dr. Jordan Parks, Sandia National Laboratories rised number of elements common to both countries. According Dr Kumar, the Indian establishment has made commitments to the nuclear material security and it is reflected in the active participation of India in all nuclear security summits. He pointed out that the Indian Atomic energy Act provides the legal framework for securing nuclear materials and facilities and the design evaluation of the physical security of nuclear materials very much depends upon the requirements and facility characterisation. His talk also touched upon the physical protection system functions and highlighted the various processes of detection, delay and response. The role of technology with focus on sensor systems and the relevance of access control in physical protection of nuclear material were heighted in his presentation. According to him the BARC has developed special nuclear material portal which is a significant contribution to the physical protection of nuclear material.

Dr. Parks highlighted that SNL over the years has evolved a number of tools and facilities for physical protection of nuclear materials and has developed an integrated security facility. The modeling and simulation of physical protection system security have been introduced and technologically it has become very useful in physical protection. The speaker also mentioned about the SNL's venerability analysis with a focus on the chareterisation, threat identification, threat facility. The SNL also provides the training to a number of institutions across the globe and the training applications comprise complex scenario development and the use of relevant tools and processes. He concluded by asserting that the physical protection of nuclear material will remain a great responsibility for the U.S and the rest of the world.

The sixth session was on "Nuclear Security at Civilian Facilities" and the panelists were Dr. Ranajit Kumar from BARC and Dr. Michael Browne, LLNL, who spoke on Reactor Facilities. Dr. Ranajit began by outlining the benefits of India's three-stage nuclear power programme which ensures control over nuclear material that is generated as spent fuel. He also mentioned that India continues to upgrade technology to develop nuclear systems that are intrinsically safe, secure and proliferation resistant. He mentioned that the serious nature of terrorist attacks have raised concerns on account of security. In reactor facilities, the threat is of Sabotage while in non-power nuclear facilities like fuel fabrication facilities the Theft is of more concern whereas in reprocessing facilities sabotage and theft both are concerns that have to be addressed. The speaker pointed to various issues related to safety such as harmonious solutions between Safety and Security requirements as this is vital because the agencies responsible for the two pillars—safety and security need not be same and therefore the plant operators and security staffs have to be molded into their respective synergetic efforts. In Conclusion the speaker pointed out that it is important to utilize the right mix of security hardware, procedure and properly trained manpower to enhance effectiveness of security, evaluate the best available and Sustainable Techniques and Instruments on reasonable long term basis. The speaker also stressed upon the fact that Indian nuclear facilities are some of the most Secured and Safe Industrial Facilities in the Country and their Security is modern, up-to-date and as per International standard.

Dr. Michael Browne started his talk by distinguishing the Nuclear Security Regime for Reactor Facilities into two as *Material Accountancy* and *Physical Protection*. Material Accountancy strives to account for and control nuclear material and to contribute to the detection of possible losses or unauthorized use or removal of nuclear material. This is done by a) Accounting system b) Key Measurement Points c) Material Balance Areas. The Speaker then gave the example of CANDU reactors to explain the material accountancy followed in such a reactor facilities. He also highlighted the interface between Material Accountancy and Physical Protection. He explained that Nuclear Material Accountancy and Physical Protection (PP) systems must be well designed and integrated in order to effectively protect nuclear material and these zones must be coordinated (or identical).
In the same session Dr. A.R. Sundararajan, Former head, Radiological Safety Division, AERB and Dr. Michael O'Brien from LLNL spoke on *Non-Reactor Facilities.* Dr. Sundararajan began his presentation by giving an overview of the components of an effective control system for ensuring safety and security of radioactive sources. He highlighted that so far no incident of nuclear material diversion has occurred but complacency must be avoided in view of the adverse consequences of such an event. The speaker supported the closed fuel cycle as a good option for India, considering the limited domestic source of uranium. The presentation also provided brief background of India's Fast Breeder Reactor Programme which began in 1985 with the PFBR being commissioned shortly. The presentation highlighted that bulk processing of plutonium from fast reactor fuel in concentrated form can be a great potential for covert diversion - especially given its high toxicity and scare value - by skilled adversaries. The key features of nuclear safety and security were highlighted. The need for an objective optimization process to support an integrated risk management was stressed upon. The speaker also mentioned that site selection and design should take into account physical protection as early as possible to address interface between physical protection, safety and nuclear material accounting to avoid any conflicts and ensure synergy among the three elements.

Dr. Michael O'Brien began his presentation by introducing the agencies responsible for nuclear security in the US. He dealt in detail about the protection philosophy of nuclear facilities, characterization of threats, protection strategies like containment, denial, insider strategy and cyber strategy. The speaker mentioned that nuclear facilities physical protection should be based on defined threat which has to be defined at the government level. Design Basis Threat (DBT) describes numbers and attributes of adversaries. The capabilities of the adversaries are defined by their knowledge, skill, weaponry, and equipment. According to him, Protection philosophy involves "Redundancy in system, Defense-in-depth in protection systems and Layered or graded protection approach". He highlighted the three points of integration which includes Nuclear Material Accountancy, Protection Systems and Protective Force which results in the Command & Control system operating in synergy protected by a protective force.

Dr. Paul Nelson, Professor Emeritus, Texas A&M University talked on "*Safety, Security and Safeguards"* in the same session. He broadly dwelt on issues pertaining to public communication about nuclear security, educational aspects of nuclear security, sample research possibilities in nuclear security and a student exchange program to strengthen cooperation between the two countries. He also underscored the importance of reassuring the public about the appropriate measures being undertaken towards nuclear security without revealing sensitive information which may be useful to any potential adversary. He outlined possible research areas for

collaboration between Indian and American researchers and proposed student exchange programmes and identified possible participating US Universities. He also suggested the existing programs like Indo-US Science & Technology forum as a useful platform for facilitating the student exchange program. He envisaged a joint DAE-DOE affiliated exchange programs in the future.

Dr. Ranajit Kumar from BARC and Dr. Michael O'Brien from LLNL made presentations on *"Training on Nuclear Materials Security*" in the same session on Nuclear Security at Civilian Facilities. Dr. Ranajit Kumar began his presentation by identifying the elements of Nuclear Security like Security Policy and Procedures, Security and Response Force. He stated that Nuclear Security was a multi-disciplinary area where "physical science disciplines must be combined with social science fields." He stressed on the fact that continuous training and improvements is key to effective nuclear security. He elaborated in detail about the proposed Global Centre for Nuclear Energy Partnership (GCNEP) which was announced by the Indian Prime Minister during the 2010 Nuclear Security Summit, Washington DC. According to him, this centre will be hosting a range of Research and Development as well as training programs for ensuring smooth security of nuclear facilities. The speaker also hinted at the possibility of inclusion of international participation in running the various activities of the centre. The speaker concluded by saying that the proposed Global Centre for Nuclear Energy Partnership also may be used for aiding Nuclear Security Training within the country as well as globally.

Dr. O'Brien underlined in his talk the importance of properly trained employees so as to have a safe and secure nuclear working environment. The proper training of employees is an area the DOE and the NNSA have placed emphasis on. He mentioned about the Vulnerability Assessment that involves a systematic qualitative and quantitative approach to evaluate Safety & Security effectiveness against theft or sabotage by different adversaries. According to him there is variety of training methods available in the U.S including National Training Center and Training at DOE sites, comprising of instructor classroom based, computer based and on-job training. Training is offered for personnel involved in physical security, training of the protective force and Personnel Security. Training of developers follows the following model that beings with Analysis, Design, Development, Implementation and Evaluation and International Training involves, Technical Exchange, Technical Workshop, Assessment of Training Needs, and Formal Training.

On second day of the workshop a special lecture was delivered by **Dr. Anil Kakodkar** former chairman AEC on the theme "**Lowering threats in sustainable development using nuclear energy"** exclusively for the workshop participants. He started his talk by giving background information about world energy scenario. He pointed out that an additional annual electricity generation needed just to reach 5000kWh average per-capita electricity (necessary for a reasonable standard of living) in non-OECD countries would amount to ~20 trillion kWh that is roughly equal to present total generation.

According to him the emerging economies in the developing world and the global development process is bound to become a more dominant factor that would push demand for energy at a faster pace as compared to growth in energy demand in the industrialised economies. Looking at the level of this additional demand and the need to minimise the threat due to climate change, increasing dependence on nuclear energy with closed fuel cycle appears inevitable. According to this is the time to look at emerging nuclear security paradigm and address the challenge of

minimising the overall risk to humanity including nuclear, climate change and inequality related risks. His presentation brought out the critical role Thorium can play in this context.
He provided various estimate world uranium resources and in his opinion, in January 2009 estimate of uranium at 6.3 million tons (includes U up to $ 260/Kg) and this should last a 100 years at 2008 consumption rate. According to him uranium in open cycle is unsustainable if nuclear energy is to meet a reasonable fraction of carbon free electricity requirements. He also pitched for the recycle of nuclear fuel in breeder reactors.
He also brought the Risk factor associated with the nuclear energy in his talk and identified risks related to Nuclear Security such as diversion of nuclear materials for weapons purposes, Threat to nuclear facility can cause public trauma and risk related to Climate Change such as Difficult to predict global consequences – Could well be much larger than what can be caused by WMDs and Development deficit and varying energy security challenges.
He emphasized the importance of Thorium, as a one stop solution to safety, sustainability and proliferation resistance. According to him Thorium enables more effective utilisation of Pu, added initially, while maintaining acceptable performance characteristics.
He suggested the best example of the Indian Advanced Heavy Water Reactor (AHWR), a quicker proliferation resistant solution for the energy hungry world. The major design objectives of AHWR include significant fraction of energy from Thorium and several passive features such as 3 days grace period, No radiological impact, Passive shutdown system to address insider threat scenarios, Design life of 100 years and easily replaceable coolant channels. He also stated that the composition of the fresh (LEU in Thorium) as well as the spent fuel of AHWR300-LEU makes the fuel cycle inherently proliferation resistant. AHWR300-LEU also provides a better utilisation of natural uranium, as a result of a significant fraction of the energy is extracted by fission of 233U, converted in-situ from the thorium fertile host.
Thorium thus offers the potential for a wider deployment of nuclear power with reduced threats (both nuclear as well as those related to climate change). He concluded by saying greater geographical spread of nuclear energy with minimised risk can be realised by Thorium-LEU fuel and there would still be a question of meeting energy needs beyond what can be supported by thermal reactors. Fast breeder reactors would thus be necessary for growth in nuclear power capacity beyond thermal reactor potential.

The seventh session was on "The Human Factor in Nuclear Materials Security". Mr Hormis Tharakan and Dr. Phil Gibbs, Brookhaven, National Lab made presentations on *Insider Threats.* Mr. Tharakan began his presentation by saying that priests, magicians, and policemen have a natural insight into human beings due to the nature of their work. He quoted lines from the Fukushima Nuclear Accident Independent Investigation Commission which said that the Fukushima Nuclear disaster was a man-made disaster and could have been avoided if the proper measures were undertaken in advance. He dwelt extensively on the issue of nuclear terrorism and the probable causes which give rise to such incidents. He attributed employee dissatisfaction as one of the most important causes which may give rise to sabotage and theft of nuclear material. Also design shortcomings which were the major cause for the three most devastating nuclear accidents along with human frailty can be major reasons which may pose threat to nuclear security. He identified the security threats emerging from suicide bombings and dirty bombs. He also gave a broad overview of security set-up in India's Nuclear Installations and their roles in enforcing nuclear security. To further enhance security, he also stressed the need for interactions between intelligence and security agencies. He also suggested that there is a need to promote

safety culture and the need for raising public awareness and reassure the public about nuclear concerns.

Dr. Gibbs began his presentation by drawing an interesting parallel between theft in a jewellery shop and from a nuclear facility. According to him, a potential adversary/insider may not necessarily choose to steal nuclear materials in substantial proportion but would rather steal in small quantities to avoid detection. He also mentioned that theft of nuclear material can also be a very slow process wherein a potential adversary/insider may choose to steal the nuclear materials over a period of time. He mentioned that there is a distinct difference in approach for analysis of protracted theft and abrupt theft. He presented a model which might be useful in analyzing theft of nuclear materials from nuclear facilities. He said that the 3 phases of protracted theft can be detected with Physical Protection, Materials Control and Materials Accounting. He concluded by saying that various modelling approaches and vulnerability analysis may be useful in preventing a potential theft of nuclear materials. In the ensuing discussion, the speaker also stressed the need for interaction between intelligence agencies and nuclear forensics.
"A Perspective on System Approach to Nuclear Security" was the theme for the last formal session. Dr. Baldev Raj, former Director of IGCAR and Dr. DV Rao from Los Alamos National Laboratory were the panelist and they focused on the theme "A Systems Approach to Civilian Nuclear Security: A Summary". Dr Raj argued that security is the watch word and many a time's less than precise expression of national and global challenges namely energy, food, water, cyber, national and nuclear. He held that nuclear security is currently imprecise as three pillars of different robustness comprising nuclear security namely safety, security (physical protection) and non-proliferation (nuclear material accounting). While deliberating on difficult arenas of nuclear security, Dr Raj was of view that terrorism, sabotage, illegal trafficking, opaque communications in domain of security are some of the complexities of nuclear security. He was of view that decision making has to be done in a realistic way with trust building and honest communication. He suggested that sometimes robotics has to be used instead of human being in nuclear security. Since more than human role, science and technology plays a rightful role for example in decontamination and rehabilitation. He emphasized international cooperation as an essential element in nuclear security today. In the end he concluded by saying one has to learn from Buddha on sustainability.

Dr. Rao said that system anlaysis is a good way to analysis the gap or communication of gap. He was of view that it was important to identify the gap in order to address it. He stated that the uniqueness of civilian nuclear security is that most nuclear facilities are one-of-a-kind, complex 'socio-technical' systems that depends on human reliability. He considered nuclear facilities and their inventories are inherently vulnerable to a spectrum of threat, in particular to intelligent adversaries and insiders. Thus, he stated that it important to safeguard the nuclear facilities at the highest levels of confidence requiring thorough analysis of even extremely low probability vulnerabilities. He also highlighted threat assessment by posing what is design based threat? He stated that the Department of Energy National Laboratories in the US have been exploring various systems modeling, simulation and analysis methods including Bayesian inferencing techniques for threat identifications, agent based simulations modeling for insider access control and dynamic flow graph methods for threat pathways. Dr Rao was of view that risk informed is one of the attributes of decision making and attractiveness i.e material attractiveness is another attribute of risk-informed-approach. He also stated that risk associated with economics of

transportation and disposal is generally not addressed while designing the system, but argued that doing so (designing) will greatly help in protection and addressing risk. In the end while discussing comprehensive risk-informed solutions, the Dr Rao highlighted 'possibility theory', Markov model approach and Agent based modeling which he felt is essential in securing nuclear facilities.

There were intense discussions among the participants in the concluding session and there were a number of suggestions on future course of actions.
Ambassdaor. Arundhati Ghose started with the issue of public awareness. She said that, it is NIAS's mandate to help the scientific community interact with public and we need to have professional communicators to spread awareness, not nuclear scientists. This will help in reaching to a diverse population. She also discussed about the -PRP- To discuss the human reliability program in detail in the next meeting. To see how this program can be improved or inculcated in India.

Amb. Saurabh Kumar suggested, the workshop would consider a joint strengthening standards, joint safety management, joint publications, or on a higher level at GICNT and IAEA. Another ambitious consideration would be formation of a public program, probably an Indo-US team – forensic investigation to prevent illicit trafficking.

In the concluding session that followed both as part of the workshop and separately between CISAC and ISSSP officials, the emphasis was on possible areas of collaboration among the scientists of the two countries. It was emphasized that the scientists themselves should take the lead and start interaction. CISAC and NIAS are at best facilitators of such interaction. The following areas were identified as possible areas of collaboration:

- Nuclear material characterization. Examine the opportunity to bring together our collective knowledge of nuclear materials and methodologies to raise our overall understanding through better and more effective databases. Search engines can also form part of the study

- Harness new, modern and cutting edge technologies and methodologies to strengthen the broad spectrum of central security infrastructure including those related to cyber security.

- Detectors, sensor systems, for NDA/security. Special emphasis on thermal imaging sensors.
- Chronometry – how to validate methods, cross validate between methods used by different countries.
- Insider threat – approaches to mitigate insider threat/terrorist threats. To go beyond standard PRP. Risk analysis. Avoid small accumulative thefts.
- Cyber security- protocols and standards. Expertise in India and US to collaborate.
- Areas of training. Exchange of scientists between facilities and participating in training programs. Critiquing programs – providing inputs on how to improve. Exchange of students between universities and laboratories.

- Seismic modelling
- *Generic modelling of nuclear installations particularly related to reactor facilities
- *Radiological and medical management of personnel in public domain: Training and exercises based on these models.
- Dispersion modelling.
- DBT and consequences of study of generic fuel cycle facility
- Integrated safety management of fuel cycle facility-There is specific interests in studying and cooperating between different labs even in the United States.
- Personnel reliability programme- very diverse in cultures, so a lot to learn from each other, learning from U.S experience, their programmes, national transportation safety board, communicating with media—aspects of outreach and public advocacy
- Regulatory aspects related to nuclear power plant decommissioning
- Criticality alarm systems
- Risk assessment of waste disposal facility
- Fire hazard analysis related to nuclear facility

*CISAC team felt that there are no restrictions in collaborating in these areas. Where required, CISAC can facilitate in identifying contacts and the procedures.