M. Sai Baba
Sunil S. Chirayath

Summary of the Meetings on Human Reliability Program in Industries of National Importance

Jointly organised by NIAS, India and Texas A&M University, USA

January 2021

National Institute of Advanced Studies
Bengaluru, India

Report NIAS/NSE/U/MR/02/2021

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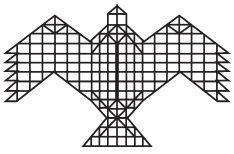

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Preface

Human Reliability (to describe human performance) is widely used in fields requiring high standards of safety, such as aviation, petroleum and chemical processes, and nuclear industries. Human behavior always poses an inherent risk through our actions or inactions. Introducing errors into the operation of a system or process. Human factors can either positively or negatively affect the performance in work place. Although human errors can be minimized through education and training/retraining programs, there are some human actions (insider actions) that could be intentional, which compromise the safety and security at the work place due to ideological, economic, political, or personal motivations. A Human Reliability Program (HRP) could ensure that individuals who occupy positions with access to critical assets/operations/sites meet the highest standards so that they adhere to safety and security rules and regulations (reliability), ensure confidence in individuals based on their character (trustworthiness) and their physical and mental stability. There are myriad ways of HRP being implemented, in some fashion or other, in industries.

A collaborative research program has been initiated between National Institute of Advanced Studies (NIAS) and Texas A&M University Center for Nuclear Security and Policy Initiatives (TAMU-NSSPI).

As part of the collaboration, a discussion meeting was organized at NIAS in April 2019 by bringing together national and international experts from diverse industries of national importance to deliberate on HRP subject matter. The discussions aimed to include safety and security case studies and lessons learned. Methodologies used for human reliability analysis were also part of the meeting discussions. The meeting had the format of panel member presentations followed by question-and-answer sessions, which facilitated further discussions. The meeting was intended to identify good practices in safety and security with respect to HRP and to continue industry informed potential future academic collaborations between NIAS and Texas A&M University (TAMU). TAMU and NIAS will work together to form a core working group to study and discuss the HRP in the context of industries of national importance in India. The first meeting had larger participation. At the end of the first meeting, organised during April 2019, the participants believed a core group should be formed with the aim of elaborating further and meet within four to six months at NIAS to continue the momentum obtained at this meeting in April 2019.

Accordingly, TAMU and NIAS jointly conducted a core-group discussion meeting on "Human Reliability Program (HRP) in Industries of National Importance" during October 15-17, 2019. The main objective of the meeting was to discuss among Indian experts the various elements of HRP and specific implementation needs in India given the Indian cultural and societal aspects. The meeting also aimed at identifying good practices in safety and security with respect to HRP and its implementation challenges. A panel discussion was conducted on October 17, 2019. At the end of the meeting, it was recommended to continue the deliberations further with a smaller core HRP group.

The second meeting of the core group was organised during October 14-16, 2020 using an online platform (Microsoft Teams) due to the prevailing COVID-19 situation. The focus of the discussions continued to be the understanding of HRP issues across the industries of national importance. Each of the identified topics were discussed in detail to analyse and identify the domains where there was further work to be done from an Indian context. A detailed report of the discussions held in the three meetings, including the two meetings of the HRP core group is presented.

The summary of the discussions held in the meeting were prepared with inputs from Sneha Yadla, Lakshmi Handsa, Vagisha Nidhi, and Amit K. Shah (Project Associates worked on the project) and the post-doctoral associate Dr. Ipshita Chowdhury.

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and

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January 2021

Abstract

National Institute of Advanced Studies (NIAS) in Bengaluru-India and Texas A&M University Center for Nuclear Security Science and Policy Initiatives (TAMU-NSSPI) in 2019 started a joint project to study human reliability program (HRP) in Indian industries of national importance. The main objective of the project study was to exchange good practices of HRP by focusing on its various elements being practiced in different countries. Based on the study, NIAS and Texas A&M intend to prepare reference documents that may be used by Indian industries of national importance for further studies and incorporation in their facilities. This report serves as the first reference document and the group will soon submit a manuscript to a peer-reviewed journal for wider dissemination of knowledge on the topic of HRP, which is currently sparse.

The objective of an HRP is to protect national security and for the safety of workers and the public. HRP, practiced in various countries, conducts continuous evaluations on individuals with access to sensitive materials, facilities, and programs. The evaluations are meant to identify any impairment in the reliability of individuals that could lead to an unsafe or insecure situation. Any signs indicating physical or emotional disorders, the use of illegal drugs, the abuse of legal drugs, alcohol or other substances, irresponsible financial management, or any other condition of individuals under HRP that negatively infringe on the safety and security of a facility or asset are evaluated. These evaluations will consist of a review by the individual's supervisor, a review by personnel security, medical assessment including psychological evaluation followed by an overall evaluation by the management resulting in a recommendation regarding HRP certification or recertification of an individual. This is in addition to the pre-employment screening of individual's conduct and aptitude for the job. The HRP requirements include random, unannounced alcohol and drug testing per year for all HRP-certified individuals. HRP includes periodic training on its requirements including the reporting aspects of unusual and concerning behaviours of other individuals. The success of an HRP depends on the commitment of individuals in the program. An HRP-certified individual is a critical element in ensuring the safe and secure operation of programs and facilities and the national security.

Three meetings consisting of US and Indian experts were held in April 2019, October 2019, and October 2020 to discuss and exchange best practices of HRP. The first two meetings were conducted as in-person meetings and were held in the NIAS campus. The third meeting was held using an online platform (Microsoft Teams) due to the prevailing COVID-19 situation. Based on the deliberations of the meetings attended by Indian and US experts from academia and various Indian industries (chemical, military, aviation, and nuclear energy) of national importance, it is understood that several elements of HRP are being practiced in India. Discussions in these three meetings pointed to the fact that the implementation mode of these HRP elements in India is different compared to that practiced in western countries because of the differences in socio-economic aspects. Given the increasing day-

to-day threats to critical industries, it is important to study and deeply understand the elements of HRP by considering it in the Indian socio-economic context before implementing it in its comprehensive form. Deliberations of these meetings also brought out the need to enhance the current practice of HRP by critically analysing the human-machine interface as well as the cognitive bias of individuals emanating from their aptitude and attitude to perform a critical task.

M. Sai Baba
Sunil S. Chirayath

National Institute of Advanced Studies
Bengaluru, India

TEXAS A&M UNIVERSITY

Meeting - 1

Discussion Meeting
on

Human Reliability Program in Industries of National Importance

April 24-26, 2019

National Institute of Advanced Studies (NIAS), Bengaluru

Jointly Organized by NIAS and Texas A&M University, USA
Technical Support from Oak Ridge National Laboratory (ORNL)

TEES TEXAS A&M ENGINEERING EXPERIMENT STATION

OAK RIDGE National Laboratory

NSSPI CENTER FOR NUCLEAR SECURITY SCIENCE & POLICY INITIATIVES

Discussion Meeting on
Human Reliability Program in Industries of National Importance

PROGRAMME

April 24 (Wednesday), 2019

Time	Topic	Speaker
0900 – 0930	**Registration**	All
0930 – 0945	Welcome Speech Opening remarks Meeting objectives	Shailesh Nayak M Sai Baba Sunil S Chirayath
0945 – 1030	Human & Organisational Aspects for Ensuring Safety in High Hazard Installations Keynote lecture	Dinesh Kumar Shukla
1030 – 1100	Introductions	All
1100 – 1130	**Tea break**	All
1130 – 1200	An Overview of Human Reliability Program	Gerhard R. Eisele
1130 – 1200	Safety and Security in Nuclear Industry, Importance of Good practices and Human Reliability	G R Srinivasan
1200 – 1230	HRP in aviation sector	K.K. Nowhar
1300 – 1400	**Lunch**	All
1400 – 1430	Roadmap to a Sustainable Human Reliability Program and Implementation Plan	Sunil S. Chirayath
1430 – 1500	The emerging challenges to human reliability Program	Reshmi Kazi
1500 – 1530	**Tea Break**	All
1530 – 1600	Behavioural Observation and Psychological Perspectives	Joseph R. Stainback IV
1600 – 1630	Design to support human systems integration	Vivek Kant
1630 – 1700	Discussions	

Discussion Meeting on Human Reliability Program in Industries of National Importance

PROGRAMME

April 25 (Thursday), 2019

Time	Topic	Speaker
0930 – 1000	Myriad ways in which things could have gone wrong but did not	Dinesh Kumar Srivastava
1000 – 1030	Impact of human element aspects on crucial industrial functions	Natesan Ramamoorthy
1030 – 1100	Human Reliability Analysis in PSA: Issues & concerns	Mahendra Prasad
1100 – 1130	**Tea break**	All
1130 – 1200	Human performance excellence in Indian nuclear industry	Satyanarayana R
1200 – 1230	Personnel Reliability in Launch Vehicle Systems.	Rajaram Nagappa
1230 – 1300	Insider Threat Mitigation Strategies for Human Reliability Program	Craig M. Marianno
1300 – 1400	**Lunch**	All
1400 – 1430	General human response guided by cognition.	Manas K Mandal
1430 – 1500	Importance of Ethical Behavior in Human Reliability	Joseph R. Stainback IV
1500 – 1530	**Tea Break**	All
1530 – 1600	HRA technique for risk assessment in nuclear power plants	Senthil Kumar Chandran
1600 – 1630	DAE's Programs & Activities or Peaceful Application of Nuclear power	Surendra Kumar Agarwal
1630 – 1700	Discussions	

Discussion Meeting on
Human Reliability Program in Industries of National Importance

PROGRAMME

April 26 (Friday), 2019

Time	Topic	Speaker
0930 – 1000	Management and Human reliability	K L Ramakumar
1000 – 1030	A system theoretic framework for modelling human attributes, Human-machine interface and cybernetics – A safety paradigm in large industries and project	Kallol Roy
1030 – 1100	Human reliability and technology disruption	Ajey Lele
1100 – 1130	**Tea Break**	All
1130 – 1200	Optimizing human reliability program by tuning probabilistic safety analysis for non-probabilistic human behaviour using human centered and user contextualized interface design	Amal Xavier Raj
1200 – 1230	Human Reliability Program: Initial and Continuous Evaluation Program	Claude R. Clark
1230 – 1300	HRP: Computer Science Perspective	Lalith Mohan Patnaik
1300 - 1400	**Lunch**	All
1400 – 1430	The challenge of HRP in the era of automation and can we find the common thread	M Sai Baba
1430 – 1530	Feedback session	All
1530 – 1600	Closing Remarks and Way forward	M Sai Baba Sunil S Chirayath
1600	**Tea**	All

Discussion Meeting on Human Reliability Program in Industries of National Importance

April 24-26, 2019

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Discussion Meeting on
Human Reliability Program in Industries of National Importance

April 24-26, 2019

Abstracts of Talks at the Meeting and Short Biography of Speakers

Significance of Human and Organizational Aspects for Ensuring Safety in High Hazard Installations

Dinesh Kumar Shukla
Executive Director of Atomic Energy Regulatory Board (AERB) and the Chairman of Safety Review Committee for Operating Plants (SARCOP)

Keynote Lecture

The safe and reliable operation of high hazard installations depends not only on technical excellence but also on individuals and the organization. Over the years, the awareness that nuclear installations are complex socio-technical systems has increased. With this, it is recognized that safety is not only a technical matter, but it also depends heavily on the behaviour of the people working in the lifecycle of high hazard installations. Therefore, Safety Management System must be developed with a thorough understanding of the interactions between technical and organizational performance to be efficient and effective.

The result of research work carried out clearly brought out the significance of human and organizational factors for continued improvement in safety performance. Each improvement reduced accident rate down to the next plateau level and further strengthening of formal procedures is no longer resulting in reduction in accident/incident rates. Deployment of technical measures, results in the stage of initiation of incident / accident being changed but not getting eliminated. Deploying more technical measures, with less attention to human and organizational factors, may not have desired impact on safety performance of the organization. Further, more emphasis on holding operators responsible and a lesser importance placed on questioning organizational and management issues is the major reason for not improving safety performance.

Latent human errors, committed by the designers, constructors may lie dormant within the system for a long time, and may get identified only after triggering an accident/event. Further, ultimately 'technical measures' (tools, equipment, design (technology) etc.) needs to be 'maintained' to perform

on demand and thus depend on 'human' (knowledge, thoughts, decisions, actions) and organizational factors (Management system, organizational structure, resources). It is inferred that human error is a **consequence**, not a **cause**. Understanding the management and organizational factors that can either reduce or identify and correct latent errors is an important element in reducing the consequences. Latent failures can occur at various levels, "strategic level (high level decision making), tactical level (line management), operational level. Thus, one of the challenges to reduce accident rates is to spot and correct latent errors/failures. Since these are related to human activity, it is important to understand what influences human activity.

In conclusion, no automated device can replace humans; humans can respond (dynamic response) to unlimited unknown situations while automated systems can respond to limited postulated events. Human activity is influenced by characteristics of the work situation, by intrinsic properties of human, and group characteristics. Care should be taken that safety management system provides balanced attention to human, organizational and technical factors while developing and implementing safety for continual improvement in safety performance.

The talk would detail some of these aspects.

Mr. Dinesh Kumar Shukla is serving as Executive Director of Atomic Energy Regulatory Board (AERB). Mr. Shukla is also the Chairman of Safety Review Committee for Operating Plants (SARCOP), which is the apex committee for review of safety issues of operating nuclear facilities in India. He is also the ex-officio member of the Board of AERB.

Before joining AERB in 2015, Mr. Shukla was serving at the Bhabha Atomic Research Centre (BARC) for about 33 years, where he rose to the leadership position in research reactor operations. He has been associated with several committees of AERB and BARC Safety Council (BSC) for the design and operational safety review of PHWRs, LWRs, reprocessing plants and radioactive waste management facilities. He has also served the Management Committee for Board of Radiation & Isotope Technology (BRIT) and the Radioisotopes, Radiation Technology and Application Committee (RTAC) of the Board of Research in Nuclear Sciences (BRNS) as a member. In this phase also, he was closely associated with AERB, as an expert for the safety review related to design and operation of NPPs and other nuclear facilities.

Mr. Shukla has been representing India in the various international forums such as IAEA- INES Advisory Committee, CNRA and CSNI of OECD-NEA, Steering Technical Committee of The Multinational Design Evaluation Program (MDEP) of NEA, Convention on Nuclear Safety (CNS). Mr Shukla has served in the Programme Committees for the IAEA- International Conference on Effective Regulatory Systems (April 2016) and the International Conference on Human Resource Development – 2018 and also chaired a session and served as panellist.

An Overview of Human Reliability Program (HRP)

Gerhard R. Eisele
Consultant - Oak Ridge National Laboratory, USA

Human Reliability Program (HRP) is designed to protect national security and also for the safety of workers and the public. This can be achieved by continuously evaluating the reliability of those who have access to sensitive materials, facilities, and programs. HRP conducts evaluations on individuals with an objective of identifying impairment in the judgement or reliability. The impairment may be in the form of physical or emotional disorders, the use of illegal drugs, the abuse of legal drugs, alcohol or other substances, and any other condition that may represent a safety and security reliability concern. The HRP evaluations will consist of a review by the participant individual's supervisor, a review by personnel security, medical assessment including psychological evaluation followed by an overall evaluation by the management resulting in a recommendation regarding certification or recertification of an individual. The HRP requirements include random, unannounced alcohol, and drug testing per year for all HRP-certified individuals. HRP includes periodic training on its requirements including the reporting aspects of unusual and concerning behaviors of other individuals. The success of an HRP depends on the commitment of individuals in the program. An HRP-certified individual is a critical element in ensuring the safe and secure operation of programs and facilities and the national security.

Dr. Eisele is nationally and internationally recognized in human and personnel reliability program development and implementation. Dr. Eisele was one of the primary architects of the Department of Energy's Personnel Assurance Program (PAP-nuclear explosive safety program), Personnel Security Assurance Program (PSAP-personnel security/insider risk program), and the Human Reliability Program (HRP-safety and security program). The HRP utilizes a continuous evaluation process to ensure that individuals who occupy critical/sensitive positions meet the highest standards of reliability, trustworthiness, and physical and mental suitability. He has also supported updating the drug testing and protective force personnel regulations. Jerry also supports the Department of Defense's Personnel Reliability Program which is under the nuclear weapons command. Dr. Eisele established the Center for Human Reliability Studies, a designated Center of Excellence by the Department of Energy which integrated personnel security, psychology, law, occupational medicine, management, and health and safety criteria into a multiphasic research program to address reliability issues and concerns. These multiple areas of concentration were instrumental in helping to develop and implement reliability programs in several foreign countries. Dr. Eisele's professional affiliation included the New York Academy of Science, Society of Sigma Xi, Society of Experimental Biology and Medicine, and American College of Toxicology. He is currently a consultant to the Oak Ridge National Laboratory, engaged in assessing the reliability and trustworthiness of individuals in critical and sensitive positions.

HRP in the Aviation Sector

Air Marshal KK Nohwar (Retd)
Director General, Centre for Air Power Studies

Aviation is a serious 'business'. It is a 'business', nonetheless, as it earns revenue for the owners of the airline. However, it has the greatest risk of failure since it has the human element in terms of the cockpit crew that is placed 'in-charge' of the lives of the passengers for the duration of the flight – from take-off to landing.

In the early days of aviation – in the middle of the last century – passenger aircraft were flown without very many technical assistants to the pilot; his complete attention was required to ensure the safety of flight. On trans-continental flights this led to fatigue which at times resulted in lack of attention at crucial stages of flight, viz. either while negotiating bad weather enroute, or landing in poor visibility/ heavy crosswind conditions.

In order to reduce the undue burden on pilots, the autopilot was invented. This relieved the pilot from the often, monotonous task of being hands-on on the controls in long duration flights. With further improvement in avionics, the auto-pilot could be coupled to the navigation system and the aircraft could 'fly' autonomously along the pre-fed route with minimal pilot interference. The natural tendency of a gyro (used for direction indicators, in addition to the magnetic compass) to 'drift' complicated the issue and often led to navigation errors. This necessitated the pilots to frequently cross-check their actual ground position – either by cross-referencing with ground features, or by cross-referencing with radio beacons en route to obtain their exact position in the air at any given time. This was a laborious task that was often entrusted to a Navigator who was always on board such intercontinental/domestic flights of long durations. There was also a Flight Signaller on board (particularly on military transport aircraft) who would carry out en route communications tasks on long cross-country/international flights.

With further improvement in accuracies of the navigation systems due to the induction of GPS-based navigation systems and the ring-laser gyro, the need for the Navigator and Flight Signaller was obviated and most airlines removed them as being part of the cockpit crew. The onus was squarely on the pilots now to navigate safely and accurately from one place to another under all weather conditions, both by day as well as by night.

Did this increase the workload on the pilot? Obviously, it did, but the training ensured that pilots were ready to undertake the rigors of intercontinental flights under all conditions with just the two-man/ woman crew.

Aviation disasters are not a new phenomenon. As we have said, flying is not a natural activity for humans. Therefore, to be put under trying circumstances in the air, requires a professionally trained pilot(s) who can respond to the situation and recover the aircraft safely. Training quality, pilot/cabin crew selection (with due emphasis on Emotional Quotient, Spatial Orientation, Psychometric Tests

for cockpit as well as cabin crew, etc.) – the entire Human Reliability Programme that is adopted by individual airlines, in my view, should be universally applicable! Crew resource management, extent of emphasis on simulator training, etc. are areas that require continuous attention by airlines the world over if 'avoidable' accidents are to be prevented.

Kishan Kumar Nowhar was born at Ambala on 07 May 1952 into an Army family, he did his schooling at Barnes School, Devlali. He is an alumnus of the National Defence Academy and was commissioned into the Fighter stream of the Indian Air Force on 24 Jun 1972. He has 3400 hours of flying to his credit. During his initial tenures at fighter squadrons, he flew the MiG-21 and later commanded a MiG-27 Squadron. A Qualified Flying Instructor and a Fighter Combat Leader, he is a graduate of DSSC, Wellington and Air War College (USA).

His command appointments include CO of 9 Squadron, Commandant Tactics and Air Combat Development Establishment (TACDE), AOC 16 Wing, AF and AOC-in-C, Eastern Air Command. His important staff assignments include Chief Operations Officer (COO) 33 Wing, Deputy Commandant College of Air Warfare (CAW), Principal Director Air Staff Inspection (PDASI), and ACAS (Plans). He has also served as Chief of Staff at Andaman & Nicobar Command, Deputy Commander-in-Chief of Strategic Forces Command (both tri-Service appointments), and Senior Air Staff Officer (SASO), Training Command. He retired as the Vice Chief of the Air Staff in May 2012. Air Marshal KK Nohwar was awarded the Vayu Sena Medal in 1998 and the Param Vishisht Seva Medal on 26 Jan 2011. He joined the Centre for Air Power Studies (CAPS) as Additional Director General on 01 Oct 2014. He took over as the Director General, CAPS on 02 May 2018.

Safety and Security in Nuclear Industry, Importance of Good practices and Human Reliability

G.R. Srinivasan
Former Vice Chairman, AERB

The wholesome approach to Safety and Security in Nuclear Industry and Good practices, from cradle to grave, to reduce dependence on Human reliability. However human reliability is still given great importance as it can result in mitigation of consequences, improve Safety, and Security. Viability and reliability. Hence efforts are put to strengthen human reliability. The Good practices are brought out. Safety and Security cultures as well as WANO (World Association of Nuclear operator) Peer review and IAEA OSART give important inputs to human reliability and these are explained. Efforts being put in the nuclear industry to strengthen and maintain human reliability are explained.

G R Srinivasan has Over 50 years of experience in Nuclear Industry, 42 years in Department of Atomic Energy, 5 years as Chairman of six committees of Atomic Energy Regulatory Board (AERB) and 7 years in GMR infrastructure. He retired as Distinguished Scientist. He held various positions, the last three being Director (Projects) in Nuclear Power Corporation of India Ltd., Vice Chairman, AERB and Advisor. Nuclear Power business in GMR infra.

Roadmap to a Sustainable Human Reliability Program (HRP) and Implementation Plan

Sunil S. Chirayath
Associate Professor of Nuclear Engineering and Director, the Center for – Nuclear Security Science & Policy Initiatives, Texas A&M University, USA

The purpose of the HRP roadmap is to guide facilities through the process of establishing an HRP at their nuclear facilities. This roadmap will present sequentially through the introduction of concepts, training, workshops, considerations, related documents, and steps needed to implement and evaluate an HRP. It is intended to assist in determining whether an HRP could be useful if successfully implemented at a given facility. Recommended steps for developing an HRP will be discussed which will include (a) evaluation of insider reliability and vulnerabilities, (b) program parameters and elements relevant to cultures and organizational makeup, (c) identifying key stakeholders, (d) identifying critical/sensitive HRP positions and regulatory requirements, and (e) developing an overall HRP implementation plan. We will discuss examples of critical/sensitive positions and the organizational relationships and administration requirements in implementing HRP.

Prof. Chirayath is the Director of the Center for Nuclear Security Science & Policy Initiatives (NSSPI) at Texas A&M University with a joint appointment of Associate Professor of Nuclear Engineering. He holds a specially appointed Associate Professorship in the Tokyo Institute of Technology where he spends 3 months per year and also is an honorary professor in the Amity Institute Nuclear Science and Technology at Amity University. His B.Sc. (University of Calicut), M.Sc. (University of Calicut), and Ph.D. (University of Madras) degrees are in Physics. He also was a Bhabha Atomic Research Center Stipendiary Trainee for one year at Tarapur in India. Previous positions include: Scientific Assistant, Indian Atomic Energy Regulatory Board, Mumbai (1991 - 1998); Scientific Officer, Indian Atomic Energy Regulatory Board, Kalpakkam (1998 - 2007); Postdoctoral Research Associate, Texas A&M University (2007 - 2010); Research Scientist, Texas A&M University (2010 - 2014), Associate Director-NSSPI (2014-2015). He has more than 28 years of experience in Nuclear Science and Engineering research, education and training with specialization in nuclear safety, security and safeguards. He teaches courses on nuclear fuel cycle and nuclear material safeguards, nuclear security and Monte Carlo radiation transport. Research interests include safeguards approaches for nuclear fuel cycle, proliferation resistance quantification & analysis, nuclear forensics, nuclear security insider threat analysis, fast breeder reactor analysis and small modular reactor neutronics coupling with thermal hydraulics. In current position, manages and directs projects funded by USDHS and USDOE, USDOS and nuclear utility companies. Has conducted nuclear security educational programs in the US and abroad for faculty and professionals. He has over 150 technical publications in referred journals (42) and peer reviewed (23) and other conference proceedings (95). He has supervised more than 34 MS thesis and PhD dissertation research of students (including 13 current students), most of them conducting research in the area of nuclear non-proliferation. He has also supervised 5 postdoctoral research associates in the nuclear non-proliferation subject area.

Emerging Challenges for Human Reliability Program

Dr. Reshmi Kazi
Associate Professor, Jamia Milia Islamia, New Delhi

Human reliability program is a critical mechanism for providing risk information concerning human performance to assist risk-prone decision-making in high reliability critical industries. With expanding information technology, human reliability in critical industries is an important requirement. A distinct measure of human reliability is effective performance of the specific tasks by an employee in a critical infrastructure. Any failure in human reliability may result in a serious breach of security in a complex system that can pose high costs. In the current state of international affairs, certain trends pose enormous risks to human reliability. With the increasing demand for global nuclear disarmament, there can be potential risks to thousands of nuclear scientists who have been operating at important positions leaving them vulnerable to terrorist groups desiring nuclear weapons. This was a matter of serious concern after the disintegration of the former Soviet Union that left many nuclear scientists unemployed. The nuclear industry may be also expected to undergo dynamic changes due to workplace trends that will lead to fewer jobs and replacement of the aging workforce. This can open up potential risks for disgruntled employees whose reliability may not remain reliable any longer. In view of the evolving trends, the human reliability program needs to be adequately prepared to meet the emerging challenges.

Reshmi Kazi is an Associate Professor at Jamia Milia Islamia, where she specializes in South Asian politics and Arms Control and Disarmament. She was previously an Associate Fellow at the Institute for Defence Studies and Analyses (IDSA). Her latest publication includes is forthcoming co-edited volume on India in Global Nuclear Governance.

Human Reliability: Importance of Ethical Behaviour in Human Reliability Program (HRP)

Joseph R. Stainback IV
Professor and Applied System Analysis Inc., Tennessee – USA

There is a link between deviant behaviours and workplace fraud. Motivators such a money and power standout whereas secondary deviant behaviours such as lies, covert behaviour, negative behaviour and mis-directions have been known to lead to much bigger issues with individuals on the verge of committing espionage or other crimes. This is why ethics (moral principles that govern a person's or group's behaviour) is an important element for consideration in HRP. Equally important are the roles of trust and good character in HRP. Ethical behaviour can be influenced by religious beliefs, family background, education, community, media influences, etc. There are several factors that can create problems in ethical behaviour such as the need for personal gain, selfish interest, competitive pressures

on profits, conflicts of interest, cross-cultural contradictions. Some national laws on falsification, unlawful contributions, bribery, etc could establish policies on ethical behaviour. In the presentation, there will be a discussion on the corporate culture and ethical behaviour with examples.

Dr. Stainback is a Research Scientist and Polygraph Examiner performing domestic and international security education, training, and research with emphasis in human reliability, credibility and trustworthiness in the workplace; preventing aberrant behaviour(s) through enhanced qualitative behavioural observations, data collection architectures, mobile / mHealth technologies including wearables and biosensors; and performing research in the causes and predictability of certain unusual / abnormal behaviours, weaknesses and disruptors within the physical, mental, and social well-being of the human state within the organizational construct. Dr. Stainback has acquired over 30 years of direct operations experience including significant industrial security related programs and projects for the Department of Energy. Dr. Stainback served as a Research Professor at the University Tennessee focused on domestic and international nuclear security matters. Dr. Stainback works closely with US National Laboratories and universities within his research capacity. Dr. Stainback holds a B.S. degree in mechanical engineering technology from Old Dominion University, an M.S. degree in engineering administration from George Washington University, and a Ph.D. degree in industrial engineering from the University of Tennessee.

Design to support Human Systems Integration

Vivek Kant
Asst Professor, IDC School of Design, Indian Institute of Technology Bombay

One of the foremost challenges in human systems integration is to accommodate the human as a systems component as well as to design in a manner so as to ensure human factors compatibility throughout the systems lifecycle. This problem of accommodating the human involves a focus on the design at early stages, to ensure operability and maintenance in later systemic life stages and is studied under the label of human machine interaction. However, the label is often a misnomer, as it obfuscates the real issue of the human machine interaction being constrained by the overall background systemic processes, as well as, the need to support human comprehension and decrease cognitive load. Thus, the problem of human reliability when viewed as a design problem requires that there is a conjoined emphasis on "what" and "how" of interaction design in human systems integration. The "how" refers to the design process and the "what" refers to the requirements analysis process. In this presentation, I will highlight the challenges of design to support human systems integration along with the associated design philosophy for human-centered design in systems. The presentation will draw upon existing research as well as my own contributions in this area.

Vivek Kant is currently employed as an Assistant Professor at the Industrial Design Centre (IDC School of Design), Indian Institute of Technology Bombay (IDC, IITB). He is cross-trained in both engineering and cognitive/behavioural sciences. His research interests are human factors, human computer interaction, history and philosophy of engineering, and sociotechnical systems.

Myriad ways in which things could have gone wrong but did not

Dinesh Kumar Srivastava
Raja Ramanna Fellow, VECC, Kolkata

The variable energy cyclotron has been operating for the last four decades without any mishap. During this period a superconducting cyclotron, a medical cyclotron, and a radioactive ion beam facility have also been set up there. It also runs an iodine facility for diagnostic and treatment at a cancer hospital. It also functions as nodal centre for the eastern zone for radioactivity related emergencies. These require a host of complex equipment requiring extreme voltages, extreme currents, extreme magnetic fields, liquid helium, liquid nitrogen etc. and handling of radioactivity.

Several international collaborations have necessitated building very sensitive detectors as well as high-performance computing facilities. As a premier nuclear installation, it is also subjected to threats. Yet, a combination of regular education and training and scrupulous adherence to safety manuals and special efforts to eliminate complacency have insured an incident-free operation.
The talk will discuss the challenges faced in achieving this.

Dr. Dinesh Kumar Srivastava is a DAE Raja Ramanna Fellow & Former Director & Distinguished Scientist, Variable Energy Cyclotron Centre, Kolkata. He is a Senior Professor, Homi Bhabha National Institute & Honorary Professor, Amity University, NOIDA. He Joined Bhabha Atomic Research Centre, Mumbai in 1971 as a Scientific Office and moved to Variable Energy Cyclotron Centre Kolkata in 1979, from where he retired a Director in 2016. He has held visiting positions in Germany, USA, Canada, and South Africa of various durations and is a Fellow of National Academy of Sciences, India and Indian National Science Academy. His present field of specialization is electromagnetic and heavy flavour probes of Quark Gluon Plasma, a matter which filled the entire universe at a few microseconds after the Big Bag, He has more than 150 papers and received several national and international awards for his research and academic activities.

Impact of human element aspects on crucial industrial functions

N. Ramamoorthy
Adjunct Professor, ISSSP, NIAS, Bangalore

Technology advances and associated development aspirations of societies and nations are well known. Among several M cited by management experts for all such pursuits (money, materials, man, methods, management, …), MAN is no less a vital element than any of the other M! The term human resources (HR), and HR development domain, are accordingly well recognized by the stakeholders. There are however requirements beyond professional - technical competencies, soft skills, management expertise, etc., especially in critical functions - due to safety of system and facility, or safety of personnel and

property. Terms like personnel reliability aspect, attitude impact, have thus emerged over a period of time. In this context, in the area of nuclear S&T related functions, concerns of nuclear security include insider-threat angle too. In light of the close linkage (if not direct overlap) of safety and security in a number of nuclear and radiation technology practices, there is a need to holistically look at the human element aspect (going beyond the insider-threat angle alone). In the era of rapid developments and continual changes, time available, or actually used, for matters of human relations and personal touch in industries, has been abysmally low or even nil in many instances. This leads to a potential risk of personnel in certain managerial and non-managerial roles and duties developing traits such as stress, depression, complacency, and so on, and in turn, endanger the organisation, be it a crucial industrial facility or national centre. Furthermore, there would be inevitably several positions in all crucial industries (particularly non-managerial or technical ones, repetitive functions), and where most personnel have low or slow career progression opportunities. The conflict of human aspirations vis-à-vis reality of career scope would then come into play, again to impact negatively or even endanger crucial functions. The idea of flagging this issue in some of the forums like the current event is to caution regarding the high risks involved and with an appeal to accept and address the same. Awareness *cum* admittance of an issue would already amount to some degree of progress towards finding means of mitigation, though not full resolution. The speaker has been citing this for nuclear and radiation facilities, and its extrapolation to similar other crucial industries is deemed worth considering.

Dr. Ramamoorthy is an expert in the field of production and utilization of radioisotopes and radiopharmaceuticals, and in the field of radiation technology applications. He has over 40 years of professional and managerial experience in development of products and services, as well as in fostering the effective and safe deployment of their applications, at national and international level. Dr. Ramamoorthy has several academic and professional accomplishments to his credit; recipient of many awards and recognition in India and at the IAEA; delivered invited talks at national and international events and published extensively. Under his research guidance, 7 students obtained PhD and 4 students obtained MSc of Univ. of Mumbai.

Dr. Ramamoorthy was President of Society of Nuclear Medicine (India) (2000) and is a Founder Fellow of Indian College of Nuclear Medicine (FICNM). During 2017-2018, he was Scientific Consultant (Nuclear and Radiation Chemistry) to the Office of the Principal Scientific Adviser (PSA) to Govt. of India, Delhi

Human Reliability Analysis in PSA: Issues & concerns

Mahendra Prasad
Reactor Safety Division, Bhabha Atomic Research Centre, Mumbai.

Human Reliability Analysis (HRA) is an internationally practiced and recognized methodology to quantify the probability of Human Error. The performance of the operator is influenced by various psychological and physiological factors called the Human Factors (HFs), sometimes also referred to as Performance Shaping Factors (PSFs). Virtual Simulations can be considered as a source of

generating human error data. The paper presents the use of virtual simulation as a tool to extract the HF information. Also, the use of Multi Attribute Utility Theory (MAUT) to identify a suitable HRA method to find the human error probability (HEP) based on the desired set of HRA attributes has been presented in this paper. The use of Bayesian Network (BN) as a tool to model SPAR-H has been presented. The paper would also discuss if time available and time required for diagnosis and action could only be the parameters for HEP quantification. The new resilience engineering paradigm, based on organizational process, is geared to model to anticipating, mitigating, and preparing for graceful recovery from future events. The paper also attempts to link the possibility of applying resilience methods for human reliability modelling in risk assessment.

Mr. Mahendra Prasad joined AERB after completing MTech and is currently working in BARC in Probabilistic Safety Section. He has been engaged in Probabilistic Safety Assessment (PSA) studies for research reactors, power reactors such as PHWR, AHWR. He was extensively work for implementation of risk informed methodology, namely, statistical prediction of wall thinning for risk-based inspection. He was involved in the development of a new methodology for estimation of human error probability and multi-unit PSA. He was involved in Level 1, & 2 PSA studies (internal and external events) for PHWRs.

Human Performance Excellence in Indian Nuclear Industry

R Satyanarayana
Site Director, Kaiga site, NPCIL

Human performance plays a vital role in the safe operation of Nuclear Power plants. Principles of Human Performance, Human performance enhancement programs, Key drivers for shortfall in Human Performance, and operating experience sharing will be covered in the presentation. Methods and programmes being adopted to address the Human Performance Reliability in Nuclear Power Corporation of India Limited also will be shared.

Mr. Ravi Satyanarayana is a graduate in Electronics & Communications Engineering in the year 1983 from Andhra University, Andhra Pradesh. He is from BARC training school batch-28 (1985). After successful completion of training at BARC, he joined Nuclear Power Corporation of India Limited (NPCIL). He has 34 years of experience in NPCIL, a larger organization under DAE in the field of construction, commissioning, maintenance, production and management in different Indian nuclear power plants. He is also responsible for the effective functioning of Contracts & Purchases, Finance & Accounts, Human Resources departments and has abundant exposure and experience at a senior level management position in the organization. He is an expert in reactor control systems; Microprocessor based computer systems, Computerized Data acquisition systems and successfully commissioned these systems in Narora Atomic Power station and Kaiga Generating Station-1&2. Based on his commendable performance, he was deputed to the 'World Association of Nuclear Operators (WANO), Tokyo Centre, Japan. He represented NPCIL during 2011 to 2013 in World Association of Nuclear Operators (WANO), Tokyo Centre, Japan.

Personnel Reliability in Launch Vehicle Systems

Rajaram Nagappa
Professor, National Institute of Advanced Studies, Bengaluru.

Launch vehicle systems are complex combinations of mechanical, chemical and electrical engineering disciplines. Some of the reliability requirements are a fallout of the design criteria used as well as the choice of materials and processes. Additional requirements emerge from assembly and integration requirements. Keeping the overall performance requirements in mind, designers tend to over specify key properties and tolerances. Personnel reliability depends upon rigor of following the laid-out procedure and maintaining a log of operations. In many systems in India, this is often a casualty. Emphasis is on greater level of industry participation and subsystems being turned out by industry, which in turn demands a greater levels of human reliability. Some of these aspects will be discussed.

Prof Rajaram Nagappa has specialized in aerospace propulsion and has worked extensively in the design and development of solid propellant rockets. He has served in the Vikram Sarabhai Space Centre, ISRO as its Associate Director. The solid propellant motors powering ISRO's PSLV and GSLV Msk II, among the largest in the world were developed under his stewardship. After retirement from ISRO, he served as Pandalai Memorial Chair Professor at Anna University, Chennai and was Lady Davis Visiting Fellow at Technion, Israel Institute of Technology Haifa, Israel. He currently, heads the International Strategic and Security Studies Programme at the National Institute of Advanced Studies, Bengaluru.

Insider Threat Mitigation Strategies for Human Reliability Program (HRP)

Craig M. Marianno
Assistant Professor of Nuclear Engineering and Deputy Director, the Center for – Nuclear Security Science & Policy Initiatives

This presentation will discuss the definition of an insider based on the three attributes; access, knowledge and authority they possess and about the categories of insiders from a nuclear security threat perspective. The discussion will also include how insider opportunity and insider malicious attempt can come together. By differentiating between the low to high consequence and low to high probability threats discussions will be made on various preventative and protective measures to mitigate insider threats. Background checks, Access control and Trusted Employee programs are presented as preventative measures whereas detection, delay, and response are presented as protective measures.

Prof. Marianno is the Deputy Director of the Center for Nuclear Security Science & Policy Initiatives (NSSPI) at Texas A&M University with a joint appointment of Assistant Professor of Nuclear Engineering. Dr. Marianno's areas of interest include nuclear counter terrorism, nuclear instrumentation development, exercise development, radiological consequence management and environmental health physics. From 2000 – 2009 Dr. Marianno worked for the Remote Sensing Laboratory (RSL) and

served in many of the National Nuclear Security Administration's emergency response teams. He has been a member and team lead for the Nuclear/Radiological Advisory Team (NRAT), Capital Region Search Team (CRST), Aerial Measurements System (AMS), Consequence Management Response Team (CMRT), Federal Radiological Monitoring and Assessment Center (FRMAC) Search Response Team (SRT) and a Captain on the Radiological Assistance Program (RAP). He was responsible for generating the dose assessment and geographic data sets for every Nuclear Power plant exercise in which the DOE participates from 2004 to 2007. From 2007 to 2009 he managed the engineering group responsible for developing custom instrumentation for the detection of radiation in unique environments. He has a Bachelor's in Physics from the University of California at Davis, a Master's in Radiological Health Sciences from Colorado State and a PhD in Radiation Health Physics from Oregon State. He is a Certified Health Physicist, a member of the Health Physics Society and a member of the Society's Homeland Security Committee.

Cognitive Science of Human Error

Manas K Mandal
Distinguished Visiting Professor, IIT, Kharagpur

Cognitive science investigates the representation of and the processing of information by human beings. All forms of human behavior are affected by cognitive processes. Erroneous behavior occurs due to a variety of human characteristics linked to faulty cognitive processing, affective evaluations and motor performance. Most researchers believe that correct, as well as erroneous response follow the same cognitive process although the individual difference in cognitive processing plays a major role in it. These individual differences factors are reflected in cognitive style, information processing strategy, perceptual distortions, memory storage, attentional span, etc. The present talk will dwell upon these factors with a possible mechanism to develop training modules in human reliability program.

Dr. Manas K Mandal is currently serving as Distinguished Visiting Professor at Indian Institute of Technology - Kharagpur. He was formerly a Distinguished Scientist and Director-General - Life sciences in DRDO [2013-2016]. Prior to this, he was Chief Controller R&D (Life Sciences), DRDO. He was also the Director, Defence Institute of Psychological Research for about nine years.

Mandal and his team were given away 'Agni Award for Excellence in self-reliance' for the contribution towards the development of 'Computerized Pilot Selection System' for Air Force. For his overall contribution to psychological sciences, he was elected as the Fellow of National Association of Psychology in India in 2012; and for his contribution to Military Psychology, he was given away the 'Technology Leadership Award' by the Defence Minister of India and the 'Scientist of the Year' award by the Prime Minister of India in 2006 (DRDO).

Dr. Mandal specializes in the areas of Neuropsychology and Cognitive Sciences. He has to his credit 12 books, over 100 research papers in international and Indian journals of high repute. His research papers are well cited with over 2000 citations.

Behavioral Observation and Psychological Perspectives in Human Reliability Program (HRP)

Joseph R. Stainback IV
Professor and Applied System Analysis Inc., Tennessee – USA

Importance of the phrase "if you see something, say something" will be discussed with reference to vigilance, paying attention to detail of seeing something for correct saying (reporting). Numerous examples of unusual/erratic behavior/appearance of individuals will be presented and what to report and how to report will be discussed considering cultural aspects. Another important aspect that will be discussed in the presentation is on the psychological perspectives taking into consideration of physical, intellectual, mental demands of working in a nuclear industry. Psychological tests can assess the ability to manage stress, assertiveness, problem-solving skills, honesty and integrity, company loyalty, anger control, etc. Some examples of Psychometric testing (Minnesota Multiphase Personality Inventory, Shedler-Western Assessment Procedure, and Dispositional Indicators of Risk Exposure) will be presented.

Dr. Stainback is a Research Scientist and Polygraph Examiner performing domestic and international security education, training, and research with emphasis in human reliability, credibility and trustworthiness in the workplace; preventing aberrant behaviour(s) through enhanced qualitative behavioural observations, data collection architectures, mobile / mHealth technologies including wearables and biosensors; and performing research in the causes and predictability of certain unusual / abnormal behaviours, weaknesses and disruptors within the physical, mental, and social well-being of the human state within the organizational construct. Dr. Stainback has acquired over 30 years of direct operations experience including significant industrial security related programs and projects for the Department of Energy. Dr. Stainback served as a Research Professor at the University of Tennessee focused on domestic and international nuclear security matters. Dr. Stainback works closely with US National Laboratories and universities within his research capacity. Dr. Stainback holds a B.S. degree in mechanical engineering technology from Old Dominion University, an M.S. degree in engineering administration from George Washington University, and a Ph.D. degree in industrial engineering from the University of Tennessee.

HRA techniques for Risk Assessment in Nuclear Power Plants

Senthil Kumar Chandran
Scientific Officer, Safety research institute, AERB, IGCAR Campus

Automation and technological developments have led to a large-scale reduction in accidents and technical failures have drastically reduced. However, the "human factor" still continues to contribute significantly to risk in many applications. It is reported that 60 – 70% of accidents are due to human errors. Therefore, to ensure safety and security in critical applications, risk assessment process should include modelling of human actions to prevent serious errors. Human reliability analysis is a highly

interdisciplinary field of study and it is challenging to model and quantify human behaviours such as cognitive thinking, stress, knowledge, training, etc. There are methods reported based on simulator training, operating experience, questionnaire, etc. to quantify these factors. Nevertheless, large uncertainty remains in establishing a universally acceptable model to be adopted for HRA.

In NPPs, HRA includes identification of human actions from safety point of view, modelling them and assessing their probabilities. Human actions include both pre- and post-initiators. Pre-initiators are those actions during calibration, testing and maintenance and post initiators include diagnosis and corrective actions. For risk assessment in NPPs, various techniques are adopted to model human actions for estimating the probabilities. This presentation will compare various HRA techniques and present their merits and demerits. The regulatory requirements in HRA for NPPs will also be briefly discussed.

Dr. C. Senthil Kumar has more than 26 years in Indian Atomic Energy Regulatory Board (AERB) and is presently Head of Risk Assessment and GIS section of AERB-Safety Research Institute at Kalpakkam. His areas of specialization include: Reliability Engineering, Risk Assessment studies, Probabilistic Safety Assessment, Software reliability, Seismic Safety, Statistical analysis, remote sensing and GIS applications, etc. He has contributed in many of the safety studies pertaining to the Prototype Fast Breeder Reactor, which is under construction at Kalpakkam, specifically in the reliability analysis of shutdown system, decay heat removal system, power supply system and in Passive system reliability analysis. He has significant contribution in the seismic re-evaluation of Fast Breeder Test Reactor. His post-doctoral study is in the area of Software reliability for computer-based systems in safety critical operations, real-time scheduling for adaptive fault tolerance in multiprocessor systems, software testing, fault injection and mutation studies. Recently, he is involved in the nuclear emergency preparedness and planning using RS-GIS techniques.

Peaceful application of nuclear power

Surendra Kumar Agrawal
Scinetific Officer, NCPW, DAE

Department of Atomic Energy (DAE) has mandate to harness the nuclear energy for providing energy security to the country. DAE has multi disciplinary research programs, focussing on peaceful application of nuclear energy in India. The talk gives a brief overview of the R&D activities of the Department.

S K Agrawal is a Member, Nuclear Controls and Planning Wing, Department of Atomic Energy since 2016. He is a graduate in mechanical engineering and has worked as shift charge engineer of research reactor Dhruva in Bhabha Atomic Research Centre till 2016. He has around 25 years of experience in the field of reactor operation, fuel handling, isotope production, system commissioning, ageing management and life extension, and safety review of research & power reactors. He is currently, working in the area of nuclear safety, security and safeguards related activities at state level, co ordinating various activities pertaining to IAEA and other international and domestic organizations.

Human Factors: Linchpin of Institutions and Organizations

K.L. Ramakumar
Former Head, Nuclear Controls & Planning Wing, Department of Atomic Energy and former Director, Bhabha Atomic Research Centre, Mumbai

The terms human reliability, human relations and human resources in the context of realizing sustained prosperity and wellbeing of Institutions and Organizations, though perceived as different connotations, have in fact, a common thread interlinking them namely improving efficiency, creativity, productivity and job satisfaction, with the goal of minimizing errors. All the stakeholders: Owners, Management and the Staff have equal responsibility and obligation in realizing this objective. The phrase "human factors" may be preferred to imply any or all of the three terms mentioned above to describe essentially interactions among three interrelated aspects: individuals at work, the task at hand and the workplace itself. Thus, human factors may be defined as the study of all the factors that make it easier to do the work in the right way by all the stakeholders for overall growth of the Organization/Institution.

Human factors play very important role in deciding the performance in workplace. The assessment of these factors particularly of the staff and people involved in critical operations and sensitive assignments have been dealt with extensively and various models are now available. In contrast, the attitude of the management professional responsible for coordination and decision-making has not received the same level of attention/scrutiny. These are also critical for the overall growth and need close scrutiny. This 'indifference' attitude or the 'blind spot' of the management (though not intentional) may also result in potentially undesirable consequences.

The purpose of the talk is to bring out these important human factors in relation to the Management approach to the functioning with some examples taken from literature. Also, overall approach that is normally pursued to ensure human reliability in a research institution engaged in chemical quality control is discussed based on the author's experience.

Dr. K.L. Ramakumar has superannuated from the Department of Atomic Energy (DAE), Government of India in 2016 after serving the Department for more than 40 years in different capacities. Before superannuation he was Head, Nuclear Controls & Planning Wing (NCPW) in DAE and also Director, Radiochemistry & Isotope Group in Bhabha Atomic Research Centre, Mumbai. His expertise in the field of nuclear technology encompasses all the stages of nuclear fuel cycle, nuclear safeguards, nuclear safety and nuclear security. As Head, NCPW Dr. Ramakumar is responsible for activities and programmes of International collaborations and Safeguards Division (ICSD), Safety and Security Studies Division (SSSD), Institutional Collaborations and Programmes Division (ICPD), External Relations Division (ERD) and Nuclear Law Division (NLD). In 2007, he organised a three-week course on Nuclear Law under the auspices of Homi Bhabha National Institute.

In addition to his scientific and technical publications, Dr. Ramakumar also delivered talks on policy related topics in: Nuclear safeguards and India's safeguards agreement Nuclear safety and nuclear security, Nuclear energy the inevitable option R&D in India: a paradoxical situation, Nuclear liability.

Other presentations of Dr. Ramakumar include subjects on nuclear safeguards as a powerful tool for ensuring nuclear safety and security, nuclear forensics, nuclear security: National requirements in the context of global governance. He was member of The Standing Advisory Group on Safeguards Implementation (SAGSI), IAEA from 2011-2016 and from 2016 is serving as member of Advisory Group on Nuclear Security (ADSEC), IAEA. He had also participated in two International conferences organised by IDSA in collaboration with Indian Pugwash Society in 2014 and another with PRIO in 2015 and delivered talks. He participated in the High-Level Fissile Material Cut-Off Treaty Experts Preparatory Group meeting held in Geneva during May-June 2018, and in the meeting of Group of Government Experts to discuss various of aspects of Nuclear Disarmament Verification, again in Geneva.

A System Theoretic Framework for Modeling Human Attributes, Human-Machine-Interface & Cybernetics - A Safety Paradigm in Large Industries & Projects

Kallol Roy
Chairman, Managing Director, Bharatiya Nabhikiya Vidyut Nigam (BHAVINI), Kalpakkam

In order to evolve a quantitative comprehension of the effectiveness, safety perceptions, trust-worthiness, etc. of an industrial worker with high-end skill-sets, an approach towards use of *mathematico-statistical* models, based on set of attributes with associated uncertainties, pertaining to the various intellectual & physical dynamics of a human worker, is presented. Since precision jobs, typical in energy, aviation & marine sectors, require either physical/manual or intellectual or both (considering planning & procedure preparation, followed by site execution) sets of attributes, along with applicable handling equipment with associated cybernetics, the mathematical models for the different work execution regimes could be different. Hence a realistic model may essentially require a framework of differential algebraic equations (DAE) containing linear algebraic equations, non-linear quadratic or higher order equations, linear homogenous or non-homogenous ordinary differential equations (ODEs) & partial differential equations (PDEs), or even higher degree/order ODEs/PDEs. For the ease of mathematical formulation, all such attributes, which represent coupled *human-machine interface* (HMI) models are considered to be *linear* & *time in-variant* (LTI), wherein the systems connected through algebraic formulations offer direct solutions, systems governed by ODEs/PDEs require analytical or numerical solvers and systems having a combination of deterministic & stochastic factors, may require a math-stat approach & may require iterative/recursive solutions of Bayesian & Markovian models.

In classical system theory domain, using the transfer function approach for a *single-input* & *single-output* (SISO) model, an equivalent concept for human, HMI & cybernetics, behaving as a feed-back control loop, can be considered, wherein, by use of the classical system theoretic techniques, in time domain or in frequency domain, aspects pertaining to *transient* & *steady-state* performance along with *stability* can be analyzed. In the present context, while performance relates to the measure of the correctness of the work executed, the transient characteristics represent the initial field trials & task-initiation, with the steady-state characteristics determining the *error-free* completion of a job.

Extending the system theoretic paradigms, by casting all the attributes in a *state-space framework*, for a *multi-input* & *multi-output* (MIMO) modeling & analysis approach, requires defining the various attributes of human skill-sets & handling tools/systems with associated cybernetics, as *states* and casting the system as *state-equations* and *measurement-equations* with system & measurement uncertainty as linear combinations. Various systems & control paradigms can be thereby addressed through a state-transfer approach, *controllability* & *observability* criteria and pole-placement criteria. Further, issues pertaining to estimation of non-measurable parameters or poorly defined parameters of *Human* attributes, may be addressed by a Bayesian approach for both *linear-time-invariant* (LTI) & *non-linear-time-varying* (NLTV) formulations and issues pertaining to *interrupt-driven* formulations of *HMI* & *Cybernetics*, may be addressed by appropriate *discrete-event* framework solvers, viz. *automatons, petri-nets*, etc. In both transfer function approach and state-space approach, the concept of *bounded-input* & *bounded-output* (BIBO) system *stability* is considered as the precision & quality of job execution within the realms of safety & availability, wherein error postulations and their mitigation actions, specific to different jobs, contribute to *stability margins*. In addition to developing first-principle mechanistic models, based on the parametric dynamics of Human attributes, applications of *Bayesian-Belief Networks* (BBN) and *Big-Data-Analytics*, are considered for evolving & quantifying behavioural patterns & safety-related trust-worthiness of individuals, for ensuring seamless cascading of the human skill-sets along with the corresponding HMI & Cybernetics.

Dr. Kallol Roy, is from the 28th batch of BARC training school and has received his B.Tech (Electrical) from NIT-Calicut, M.Tech (Electronics Design) from CEDT, IISC-Bangalore and a PhD (Fault Diagnostics) from Systems & Control Dept. IIT-Bombay. He was also a Post-Doc Fellow at the University of Alberta (Canada). Prior to his assumption of the present position as CMD, BHAVINI, where he was in charge of total maintenance management, ageing management & refurbishing of all the research-reactors at BARC and also commissioning of new research & test facilities. He had also served in many AERB & BARC safety committees, BRNS committees and was also a Professor of HBNI. His specializations are in Total Plant Maintenance Management, System Fault Diagnostics, Uncertainty Estimation & Modeling in Instrumentation & Measurement Systems and EMI/EMC Modeling in Computational Electromagnetics framework. Presently, apart from his regular assignments, as CMD Bhavini, Dr. Roy continues to pursue studies on application of Bayesian Estimation techniques for Project Scheduling & Technology Forecasting and Data Analytics for Plant Performance Optimization.

Human Reliability and Technology Disruption

Ajey Lele
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Disruptive technology is all about existing technology getting replaced either by an enhanced version of that technology or offering a totally new technological option. Such technologies make existing technologies obsolete. These technologies could get developed in various fields from hardware to software to networks or combination of these fields. Broadly, technology disruption in the civilian field leads to change in business practices while in military domain, leads to changes to the military

doctrines. Experts believe that 21st disruption could occur/is occurring mainly in fields like robotics, ICT, materials and biotechnology. Technologies like artificial intelligence (AI), internet of things (IoT), additive manufacturing, UAVs/drones, DNA technologies, strategic minerals and few more are getting identified as disruptive technologies. These technologies are expected to impact both civilian and military fields.

What impact would the disruptive technologies have on human reliability? Some of these technologies are likely to remove the human from the 'loop'. The presence of human from designing, manufacturing to sales sector is expected to decrease in the era of Industry 4.0. AI supported Smart Factories could lead to various social tensions. In the military arena with the advent of autonomous weapon systems, the decision-making powers are expected to shift from humans to machines. It would be of interest to assess how humans would behave under such circumstances.

It is a common experience that human actions are a cause of vulnerability for industrial systems. Human Reliability Analysis (HRA) is a structured approach used to identify potential human failure events. However, in the era of technology disruption are the existing frameworks of HRA relevant? Are the prevailing methods of human reliability modelling useful in modern context? Would the absence of human from the 'loop' make the art & science of assessing human reliability irrelevant or would highlight the need to have a fresh look at this concept and emphasize the need for additional research on this subject?

There is a need to identify possible positive and negative behavioural aspects of humans at the backdrop of possible technology disruptions. It is important to recognize that; the process of automation is made by the humans and for the humans. Hence, assessment and estimation of possible human actions are always important in the final analysis.

Dr. Ajey Lele, is currently working as a Senior Fellow at the Institute for Defence Studies and Analyses (IDSA), New Delhi. He started his professional career as an Indian Air Force Officer and took early retirement from the services to peruse his academic interests. His specific areas of research Space Security and Strategic Technologies. He has various publications against his name.

Optimizing Human Reliability Program by tuning probabilistic safety analysis for non-probabilistic human behaviour using human centred and user contextualized interface design

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Limitation of Probabilistic Safety Assessment Models are known. Perception, Judgement, Discernment and Discretion influence critical decision during incidents. Such decisions are taken by operators, often relying on a perceived reality created by an interplay of Technology, People, Organizational, and External Factors. Except for technology and feedback from instruments, the decision is largely

influenced by human perception, judgement and decision. That is qualitative interpretation rest of the rules, processes, procedures, competence, alertness, etc. of the people involved. There is a need to optimise interface between the machines, processes, data, interpretation and decisions.
Advancement in technology, data science, digitalisation and automation should be leveraged for optimum human decisions reducing incompatibilities in interfaces. A human-user-centred interface design is a possibility now. Such designs, a holistic approach, should enhance reliability of inputs, overcoming perceptual flaws, appropriateness of rapidly changing context, leading to better judgement and timely decisions. It is proposed to develop a case for human centred and user contextualised interfaces to optimise human reliability programmes.

Dr. A. Xavier Raj, an experienced Anthropologist and Development Sector Specialist, is Professor of Entrepreneurship Management at LIBA, Chairperson of C.K. Prahalad Centre (LIBA), Adjunct Faculty (Honorary Position) in National Institute of Advanced Studies (NIAS), IISc. Campus (Bengaluru) and Executive Director of Loyola Inclusive Innovation Impact Centre (L3iC) at Loyola Campus (Chennai). Earlier Xavier has worked with global market research and consulting firms: 15 years with Blackstone Market Facts (US firm), Synovate (British conglomerate), and Ipsos (French company). During this tenure, Xavier established two profit generating specialist divisions. Core expertise include Strategic Consulting (multi country), Humanitarian Assistance, Design Thinking and Inclusive Innovation. At National Institute of Advanced Studies associated with School of Natural Sciences and Engineering involved in consultations – nuclear energy, artificial intelligence, inclusive manufacturing, science communication, etc. Earlier at AICUF supported a number of campaigns in the area of human rights including marginalized segments such as women, children, tribe and Dalits. As an Entrepreneur founded TSP Consultancy Services Pvt. Ltd., Serendip Boutique, TechLoyola Organics and YX Infra. Currently mentoring 10+ start-ups at Loyola Inclusive Innovation Impact Centre (L3iC). Taught in University of Madras – Social, Cultural, Applied, Ecological and Developmental Anthropology / Sociology, Culture and Management and Business Sustainability.

Initial and Continuous Evaluation in Human Reliability Program (HRP)

Claude R. Clark and Gerhard R. Eisele
Consultants - Oak Ridge National Laboratory, USA

A system for initial and continuous evaluation of individuals certified in HRP positions is considered important for the success of HRP. Initial evaluation is intended to reduce the likelihood that unreliable applicants will be placed in HRP positions. Continuous evaluation checks the information, including security concerns, relevant to the individual's suitability to perform HRP tasks safely and reliably. Supervisor's continuous evaluation importance will be discussed as well as the need for continuous medical evaluation will be presented. The management process for removing individuals from HRP duties and notifying the security will be discussed. The importance of maintaining positive employment standards and the role of leadership for the sustainability and success of the HRP will be also part of the presentation.

Mr. Clark provides technical, program, and project support in the areas of nuclear operations, human reliability, fitness for duty, insider threat, infrastructure development, management assessment, and training. The Security Culture, Insider Threat and Human Reliability Programs, including Fitness for Duty are based on National, International and IAEA Standards to support nuclear non-proliferation program initiatives and objectives and related DOE, DOS, and DHS initiatives. His career has included senior management positions with nuclear power companies in the United States, Head, Nuclear Power Engineering Section at the International Atomic Energy Agency in Vienna and as the first Director, Education and Training with the Federal Authority of Nuclear Regulation in the UAE. He has also provided management consulting with the International Atomic Energy Agency through a South Korean project to develop e-learning modules focused on all 19 infrastructure issues of the IAEA Milestone document and new comer countries for infrastructure and organizational management and all Stakeholder involvement. These projects, including safety, security and safeguards were utilized for providing guidance for countries entering the nuclear power regime for the first time. His work has included extensive travel and consulting opportunities worldwide.

The challenge of HRP in the era of automation and can we find the common thread

M. Sai Baba
TV Raman Pai Chair Professor, NIAS

Advancements in the domain of Science and Technology, facilitate more and more automation. When it comes to process and operations, it is seen that the component of automation is getting enhanced. With the advent of robotics and AI, it is envisaged that time is not far when totally automated industrial processes become many. The automation is guided by human understanding of the process and designing the processes amenable for complete automation. The role of the human reliability program in such a scenario and the challenge of finding the common thread across the diversified industry would be briefly discussed.

Prof. M. Sai Baba, Outstanding Scientist and formerly Director, Resources Management Group, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam and Senior Professor, Homi Bhabha National Institute. Presently holding "TV Raman Pai Chair Professor" at National Institute of Advanced Studies, Bengaluru and working in the domain of Science Communication and Risk Communication.

Present work includes, obtaining effective and informative insights on managing public perceptions and public acceptance of public risks associated with new and emerging technologies, through science and technology communications. Developing platforms for enhancing interaction between scientists and public using conventional and nonconventional media of communication.

Dr. M. Sai Baba has made significant contributions for implementation of several high impact activities of relevance to IGCAR and the Department of Atomic Energy. A key member of the team that established and nurtured the research in the domain of mass spectrometry at Chemistry Group to international

acclaim. Carried out extensive thermo-chemical investigations and modelling to assess fission product tellurium induced clad attack in fast breeder reactors. Instrumental in standardizing methods for analysis of nuclear fuel solutions irradiated in a nuclear reactor to determine burn-up (a measure of how much energy has been extracted from a nuclear fuel in a nuclear reactor), nuclear material input accountability and fission gas analysis of fast reactor fuels. Established a new experimental program for measurement of equilibrium vapor pressures by transpiration method based on Thermogravimetry.

Made outstanding contributions to realize the dream of starting the BARC Training School programmes at IGCAR. Played an important role in formulating the procedures and implementing the Homi Bhaba National Institute (HBNI) programmes at IGCAR, right from its inception.

HRP: Computer Science Perspective

Lalith Mohan Patnaik
Adjunct Professor and INSA Senior Scientist, National Institute of Advanced Studies, Bengaluru

The talk would cover the developments in the domain of Computer Science and the implications to the Human Reliability Program.

Prof. L M Patnaik is an INSA Senior Scientist and Adjunct Professor with the National Institute of Advanced Studies, and Honorary Professor with the Department of Electronic Systems Engineering, Indian Institute of Science. Prior to this, he was a Professor with the Department of Computer Science and Automation at the Indian Institute of Science and was the Vice Chancellor of Defence Institute of Advanced Technology, Deemed University, Pune between March 2008 - August 2011. He has served as the President of the Advanced Computing and Communications Society, and the Computational Intelligence Society of India. He is a Distinguished Lecturer of the IEEE Region 10.

He is Fellow of the IEEE, and The World Academy of Sciences, Trieste, Italy, The Computer Society of India, Indian National Science Academy, Indian Academy of Sciences, National Academy of Sciences, and Indian National Academy of Engineering. His name appears in Asia's Who's Who of Men and Women of Achievement and Directory of Distinguished Computer Professionals of India. He has served on several significant committees of leading professional societies such as the IEEE, CSI, IETE and Institution of Engineers. He is also in the review and policy committees of Government agencies such as the DST, DBT, MHRD, CSIR, DOS, UGC, AICTE, DRDO, DIT and UPSC. He is on the Yash Pal committee to advise on Renovation and Rejuvenation of Higher Education. He has been a part of reviewing committee of AICTE, UGC, NBA, and Technical Education Quality Improvement Program and has significantly contributed to improving quality of technical education in the country.

Alpana Goel
Director & Head, Amity Institute of Nuclear Science and Technology, Amity University

Dr. Goel is working as Director at Amity Institute of Nuclear Science and Technology Amity University Uttar Pradesh India earlier she was Head of department of Physics, Amity Institute of Applied Sciences, Amity University Uttar Pradesh. She has more than 30 years teaching experience of teaching UG and PG students. Her Ph.D. is in Nuclear Physics from IIT Roorkee. She has worked as a Postdoctoral fellow in Delhi University. Her research Interest includes areas of Nuclear Structure Physics and Nuclear Security. Presently, she is involved in developing theoretical information about Super-deformed -nuclei and have published more than 35 papers in very reputed National and International Journals. Some of the good papers are in Physical Review C, Physics Letters, Nuclear Physics A, Pramana etc. She wrote four books for engineering students. Under Dr. Goel two students had awarded Ph.D. Degree in Nuclear Physics and three students are registered. She is a life member of IAPT, IANCAS and INS. She is faculty advisor of INMM Amity University student chapter. She is the World Institute for Nuclear Security (WINS) Ambassador of India. Presently working as chair of WG-II, International Nuclear Security Education Netword (INSEN), IAEA.

Anil Kumar Jain
Head HR and Training, Institute of Petroleum, Dehradun

Dr. Anil Kumar Jian is currently Head HR, Training, IPR International S&T Affairs, Indian Institute of Petroleum, Dehradun. He obtained PhD from IIT Delhi. Dr Anil Kumar Jain has over 20 years of experience in management of Intellectual Property mainly identifying research work for filing patents, filing of new patent applications in India and foreign courtiers, respond to patent search and patent examination report, providing commercial working report. As Coordinator of International Science & Technology Affairs (ISTAG), coordinated all the activities to strengthen our International collaboration with foreign countries through Bilateral Programme of cooperation sponsored by various funding agencies. His responsibility includes organizing sponsored training courses for industry clients mainly refining industry. Expanded training programmes into a range of highly specialized and custom designed training courses for different clients not only in India but also abroad.

VS Ramamurthy
Emeritus Professor and former Director, NIAS

Prof Ramamurthy is an Emeritus Professor at NIAS and was former director of NIAS. He is well known as Indian nuclear scientist with a broad range of contributions from basic research to science administration. Prof Ramamurthy started his career in Bhabha Atomic Research Centre, Mumbai in the year 1963. He has made important research contributions, both experimental and theoretical, in many

areas of nuclear fission and heavy ion reaction mechanisms, statistical and thermodynamic properties of nuclei, physics of atomic and molecular clusters and low energy accelerator applications. Prof Ramamurthy was awarded one of the top civilian awards of the country, the Padma Bhushan, by the Government of India in 2005, in recognition of his services to the growth of Science and Technology in the country.

Prof Ramamurthy was fully involved in science promotion in India as Secretary to the Government of India, Department of Science & Technology (DST), New Delhi During 1995-2006. He was also the Chairman of the IAEA Standing Advisory Group on Nuclear Applications for nearly a decade. After retirement from government service, Prof Ramamurthy, in addition to continuing research in Nuclear Physics in the Inter-University Accelerator Centre, New Delhi has also been actively involved in human resource development in all aspects of nuclear research and applications. Prof Ramamurthy is also a Chairman, Recruitment and Assessment Board, Council of Scientific and Industrial Research and Member, National Security Advisory Board.

Anurag Mudgal
School of Technology, Pandit Deendayal Petroleum University

Dr Anurag Mugdal is a faculty at School of Technology, Pandit Deendayal Petroleum University, Gandhi Nagar. He did his Masters and PhD from IIT Delhi in the domain of Thermo fluid mechanics and applied mechanics. He is guided several undergraduate and post graduate students. Four of his students are currently pursuing PhD under his supervision. He is providing expertise solutions in mechanical engineering and heat transfer to a number of industrial clients. He is currently handling several R&D projects funded by agencies like DST. He is the Indian coordinator of India – H2O.

Ritu Raj
Scientific Officer, AERB, Mumbai

Ritu Raj is working in Directorate of Radiation Protection and Environment (DRP&E) of Atomic Energy Regulatory Board (AERB). He is a Chemical Engineer and Homi Bhabha medalist from 6th Batch of BARC training School at IGCAR, Kalpakkam. He joined AERB in the year 2012. He was involved with commissioning activities of PFBR for more than 3 years. Presently he is working in the area of Emergency Preparedness of Nuclear Power Plants and involve in preparation of nuclear emergency related documents.

Bindu Malini
Post-Doctoral Fellow, Indian Institute of Science, Bengaluru

Bindu Gunupudi completed her PhD at the University of Birmingham, UK in 2015 in the field of superconducting device physics and is currently pursuing her postdoctoral research in experimental Quantum Device Physics at the Indian Institute of Science, Bangalore. Along with a penchant for research in experimental physics, her interests include communicating research in various fields of science to a general audience.

Sneha Sundari Y
Research Assistant, National Institute of Advanced Studies

Sneha did her master's in plant biology and biotechnology. She is part of the science communication team at NIAS. Some of the works she has carried out at NIAS included studying conflicts arising out of implementing projects relating to science and technology in Indian society.

Summary of deliberations of the Discussion meeting Deliberations on Human Reliability Program in Industries of National Importance

Mr. D. K. Shukla spoke about the significance of the human organizational and technical factors in human reliability and understanding the human factors. His talk emphasized the need for providing a balanced attention to human, organizational, and technical factors while developing and implementing a safety management system. He recalled the Three Mile Island and Chernobyl nuclear reactor accidents and highlighted the significance of human organizational factors. Through these two examples of nuclear reactor accidents, he brought out the significance of human and organizational factors for continued improvement in safety performance. From the analysis of the accident rates, it can be seen that each improvement reduced the accident rate down to the next plateau level and mentioned that further strengthening of formal reactor safety procedures is no longer resulting in a substantial reduction in nuclear accident/incident rates. He discussed in detail about the latent human errors committed by designers may lie dormant within the system for a long time and may get identified only after triggering an accident/incident. Understanding the management and organizational factors that can either reduce or identify and correct the latent errors is an important element in reducing the accident/incident rates.

Dr. G. R. Eisele gave an overview of the development of HRP and the importance of human reliability in different fields. He mentioned that safety and security are mirror images of HRP. He emphasized the necessity of having security along with safety as a component of HRP. He emphasized the importance of continuous evaluation and past evaluation of employees to combat insider threats. Another important aspect of HRP he discussed was the need for training and retraining employees. He went through the components of HRP such as review with the supervisor, medical evaluation, psychological evaluation, and review by safety/security personnel.

Eisele further elaborated that HRP is a security and safety reliability program designed to ensure that individuals who occupy positions with access to certain materials, facilities, and programs meet the highest standards of reliability and physical and mental stability. This objective is accomplished through a system of continuous evaluation that identifies individuals whose judgment and reliability may be impaired by physical or mental/personality disorders, alcohol abuse, use of illegal drugs, the abuse of legal drugs or other substances, or any other condition or circumstance that may be of a security or safety concern. In the US, HRP certification is required for individuals assigned to or applying for a position that: allows an individual to have access to sensitive materials (nuclear and non-nuclear), facilities, and programs. Before nomination to the HRP, the Manager or the HRP management official must analyse the risks the position poses for the operational program. HRP requires a security clearance granted by a governmental entity to have access to classified/sensitive information, materials, and facilities on a need-to-know basis. HRP instruction must be completed. Individuals who occupy certain HRP positions may be required to complete a counterintelligence evaluation. Review of security concerns of the HRP candidate or HRP certified individual must be conducted by supervisor

and medical assessment needs to be performed. Also, management evaluation and personnel security review are needed. Medical assessment includes illegal drug use and alcohol testing.

Mr. K. K. Nowhar' s talk discussed a few case studies of accidents in the aviation sector and the takeaway lessons from those accidents. He spoke about the human factors that come into play in critical situations. He addressed the issue of hierarchy in the aviation sector, the importance of understanding the situation at hand, and the need for communication with the crew resource management. His talk emphasized the necessity of the pilot to understand the theory and working of the aircraft to react appropriately in the time of need.

Mr. G. R. Srinivasan's talk covered the commitment of the nuclear industry in India towards safety and security. He spoke about the safety practices that have been adopted from other industries and the sharing of practices between different industries in safety. He spoke about instrument reliability in the nuclear industry. He mentioned how a detailed design review helps in accident reduction and management, if necessary, to reduce the risk. He stressed the importance of designing the plant by keeping in mind the necessity of both security and safety components. He went through the practices followed by the nuclear industry to strengthen human reliability. He spoke about the safety culture in an organization and how it is supposed to be inherent rather than induced.

Dr. Chirayath's first talk covered the elements of HRP to inform more detailed deliberations on it later. He also discussed the benefits of having an effective HRP in industries of national importance. His talk gave an overview of the key components that are to be considered while developing an HRP. He gave a tentative five-step procedure in establishing a new HRP beginning with the forming of an executive committee to the final implementation of HRP. He went through the different individual positions in the institution and the organizational relationship that is expected to function in HRP. He concluded the talk by emphasizing the benefits of a program that creates HRP trained individuals and pointing out the eligibility of the individuals to be certified by the HRP.

In his second talk, Dr. Chirayath dealt with the topic, "A Roadmap to a Sustainable Human Reliability Program and Implementation Plan". The purpose of the HRP Roadmap is to guide countries/facilities through the process of establishing an HRP at their nuclear facilities. This roadmap is presented sequentially through the introduction of concepts, training, workshops, considerations, related documents, and steps needed to implement and evaluate an HRP. It is intended to assist countries and facilities in implementing an HRP at a given facility. The fundamental implementation steps for establishing an HRP at a facility where no HRP currently exists:

a) Evaluate and accept the possibility of an insider threat
b) Develop a preliminary regulatory basis for implementation
c) Identify and establish an executive committee/stakeholders/implementation team
d) Prepare a draft HRP plan
e) Determine resource needs
f) Submit the HRP plan for approval

g) Train personnel to fill HRP positions
h) Conduct initial security evaluations on HRP candidates
i) Enroll identified personnel and conduct periodic reviews in keeping with the plan
j) Report results and take necessary actions

Details of each step are provided in the presentation slides and the full document. An industry of national importance strives to employ the most reliable and trustworthy individuals. It is important that all employees within such a facility clearly understand their role and their impact on co-workers, the environment, and the country. A clear security foundation is vital, and an HRP sets a standard for employees who occupy sensitive positions.

Dr. Kazi's talk brought out the importance of human reliability in critical industrial environments. Her talk highlighted the status of the international nuclear industry and its challenges when it comes to human reliability. She further discussed about the necessary aspects of HRP including screening, continuous evaluation, and implementation of the program. She emphasized the challenges in developing an efficient HRP including the infringement on privacy, personal freedom, and professional ethics. She indicated that the state of international affairs also raises concern about the emerging challenges to HRP. The talk also stressed addressing a disgruntled employee situation so that such an individual does not turn into an insider threat. Her talk mentioned education, training, and developing trust and responsibility as essential components of an HRP.

Dr. Kant's talk gave us an interesting perspective on how engineering, design, and psychology can come together in mutually supportive ways and how we can use design to support human systems integration. His talk revolved around how to design in a manner to support humans in any kind of large-scale system, with three key ideas of conceptual structures of designers, operator studies, and interactive design. He discussed how to design systems in which humans are an integral part while acknowledging human cognition. He mentioned the importance of establishing design requirements based on operator studies and cognitive work analysis. He has given insights into cognitive work analysis that help in understanding how humans are taken as part of the overall technological system. He presented a formative view of design that supports human variability and takes in human constraints and ecological psychology where personnel and environment together result in human behaviour. He discussed the operator behaviour studies in the 1970s and 1980s that resulted in the conceptual framework and their role in systems design. He discussed extended cognitive work analysis, the changing dynamics of the human-machine interface, and the generic framework for humans in socio-technical systems.

Dr. Srivastava gave an overview of the environment of the Variable Energy Cyclotron Centre (VECC) in Kolkata, where a room temperature cyclotron has operated since 1977. He went through the precautionary steps that are being applied at VECC to prevent any kind of accidents. He emphasized about the necessity of strict adherence to safety guidelines at all times and the importance of training and licensing protocols. He stressed establishing a good work environment for employees to grow and be recognized for their contribution to the organization. He discussed the importance of training and

counselling for the employees along with a regular check on the equipment. There can be cases of oversight due to complacency and trust in the functioning of the equipment which must be avoided by a regular checklist. He also mentioned the role of friendship and comradery among the staff which can be a part of an HRP. He gave insights on different psychological situations that can influence the performance of employees and various human factors that play a role in a work environment.

Dr. Ramamoorthy' s talk covered the impact of human element aspects on vital national industries and several industry-like service entities. He emphasized the need to consider holistic human element aspects beyond the overlap of insider threat and the safety-security angle. He mentioned the influence of human elements like individuality, society, and the background of a person. The talk also shed light on the privacy of the individuals and human rights requirements to be considered while developing an HRP. Along with the critical industries, the talk also discussed the other industry like entities where human reliability plays a role. He analyzed the risk factors and challenges for human reliability. He put forward an excellent point for the future development of HRP such as mapping and compiling known good practices and lessons learned in major organized industry and industry-like service entities, designing and evolving curriculum - syllabi for holistic HRP for consideration and adoption by vital industries and industry-like service entities and outreach events for enhancing awareness and fostering HRP practice exercises by vital industries and industry-like service entities.

Dr. Prasad spoke on the topic of quantification of human reliability and probabilistic safety assessment in the nuclear industry. He also highlighted the need for the accounting of potential human error for modelled accident sequences. He mentioned the challenges involved in developing simulators to predict probable situations. The main challenge is the human factors data that are available for quantification. The talk went through the importance of virtual simulation models and discussed the state-of-the-art technology that is being developed in the field. He discussed the prevailing methods of HRA such as MAUT, SPAR H, THERP, Bayesian method. He mentioned the changes required in current HRA models and talked about PSF latency, issues, and gaps in training personnel.

Mr. R. Satyanarayana's talk gave insight into the strategies that are currently in use for human reliability. He started the talk with strategic objectives to anticipate and prevent active error at the job site and identify and how to eliminate latent organizational weaknesses. He emphasized the role of organizational factors in human reliability. He discussed the types of errors that can lead to accidents and error precursors that must be considered for human reliability. He gave an idea about the error prevention techniques that are impactful to human reliability. He addressed the importance of finding latent errors either in design or human errors that are usually not realized until late. The talk stressed organizational attributes and eliminating latent organizational weaknesses as a major factor for establishing a strong HRP.

Dr. Nagappa started his talk by introducing the launch vehicle systems of the Indian Space Research Organization, and then touched upon how reliability works in this frame and certain examples where human reliability issues have come in place. He highlighted the Polar Satellite launch vehicle, a four-stage system, which is a complex system of systems, and carries a large mass of hazardous substances. He talked about safety in the component, subsystems, systems, and finally the integrated vehicle and

how safety is intimately connected to the reliability, before moving on to the safety measures taken in the buildings, operations, processes, workplace, environment, transportation, and handling. He then talked about the extreme caution to be given to the characteristics of Expendable Launch Vehicles. Human reliability issues are present in any complex system, and the launch vehicle systems are no exception. Practically in every operation, there is more than one person involved, people are asked to follow the well-documented procedures. Continuous efforts are made to talk to the people to explain that the efforts they put in will take the satellite into orbit for a long period. Once the people are taken into confidence, they will be the ones to report once any problem arises. Taking into consideration and emphasizing what went wrong rather than who did wrong, enhances the human reliability factor. Also, post-tests are extensively done even for successful launches, which reconfirms the design or brings out design weaknesses.

Dr. Marianno started his talk by defining the term insider and the necessity to accept that insider threats are possible, and an insider can be anyone. The talk dwelled into the categories of insiders and the course of action that they can take. He discussed the actions that an insider can commit based on their capability and the adaption to the response necessary to identify and mitigate the threat. He mentioned the opportunity and motivations that trigger an insider attempt. The measures to mitigate insider threat and the process of risk evaluation were discussed. He emphasized the importance of observational awareness programs. He went through the system approach to prevent and protect against insiders in detail. Analysis of insider events and grouping method, which can be applied during the development of HRP was suggested.

Dr. Marianno, further discussed about insider threat mitigation strategies to support HRP. According to the International Atomic Energy Agency (IAEA) an insider is defined as any individual with authorized access to nuclear facilities or nuclear materials in transport, who might attempt unauthorized removal or sabotage, or who could aid outsiders to do so. There are different categories of insiders (passive and active). Active insiders could fall into the category of violent or nonviolent and a violent insider could be sub-classified into rational or irrational. An insider opportunity for a malicious act is created because of their access, authority, and knowledge. Hence, these three insider attributes need to be carefully controlled to prevent the opportunity for a malicious act. Insider motivations could be ideological, political, financial, or personal. Insider motivation and insider opportunity present together with an insider can lead to an insider attempt of a malicious act. There is no one-shot solution to mitigate insider threats. HRP can support insider threat mitigation. Also, there should be preventive and protective measures to mitigate the insider threats. Preventive measures include pre-employment screening, reducing insider motivations through various employee assistance and satisfaction programs, minimizing opportunity through measures such as controlling access by grouping employees and compartmentalizing information/knowledge. Protection measures include detection, delay, response, and consequence mitigation. Details of preventive and protective measures in mitigating insider threats are provided in the presentation slides and the full document.

Prof. Mandal spoke on the topic of cognition of human response. Cognition affection and action are the three facets of human response. Cognition is a process, which forces us to commit errors. He walked us through the cognitive architecture of human response and the trans-disciplinary role of

cognitive science. He gave an overview of models in cognition and stressed the functional models of cognition. His talk dwelled on the cognitive distortions and challenges in deficiency and efficiency models of cognition. He mentioned automation, autonomy, and augmentation and the importance to develop technologies in parallel to human capabilities, and the necessity to develop programs related to human reliability in this domain. He discussed how most researchers believe that correct, as well as erroneous responses, follow the same cognitive process, although the individual difference in cognitive processing plays a major role in it. These errors are identifiable through cognitive assessment tools designed for this purpose. Since no such test is available to detect these errors comprehensively as of now, it will be better to develop and standardize such a battery of tests, keeping the safety-sensitivity of Industry in mind. Some of these errors in our cognitive process are modifiable as well. A suitable training program may be developed based on cognitive principles. These training modules will add great value to HRP.

Dr. Senthil Kumar's talk was on human reliability assessment techniques in nuclear power plants (NPPs), where he highlighted the regulator's approach to risk-informed decision making, where deterministic and probabilistic safety assessment (PSA) form part of the process. The need for quantifying human errors for PSA and various human reliability models being adopted internationally for estimation of human error probability were brought out. The steps involved in human reliability analysis for NPPs include identification and screening of human actions, modelling of various human factors and assessing the non-response probabilities. The HR models viz., THERP, ASEP, and HCR adopted for Indian NPPs were explained in brief.

Mr. S. K. Agarwal gave a brief overview of the program and activities of the Indian Department of Atomic Energy (DAE). He spoke about the engagement of DAE in developing nuclear technology in India and its developments in radiation technologies and their applications in different sectors. He emphasized DAE's contribution to support basic research in nuclear technologies and various frontiers in science.

Dr. Ramkumar's talk focused on the interplay between management and human reliability. He mentioned the equal importance of both the human-machine interface and the human-human interface. Human reliability is a two-way process, he mentioned, where the entire organization should be considered. He included human relations development, human resources management, and human reliability assessment in human factors that contribute to the overall growth of the organization. He interconnected the literature in the past that are relevant for understanding human reliability giving examples from Chanakya and Ramayana that represented lessons of human reliability. The talk gave an excellent example of trust-building in an organization. He also gave examples of situations where poor management practices have caused irreversible damage to the organization and raised the question of how to handle such issues through HRP. He gave an idea about the steps involved in ensuring quality measures in an analytical laboratory in a nuclear research institute.

Dr. Roy's talk gave a quantitative perspective for developing HRP. He emphasized the importance of teamwork and listed the series of factors that are necessary for safety measures in large industries.

He spoke about developing appropriate mathematical-statistical models for the human worker along with associated Human Machine Interface (HMI) and cybernetics for enhancing both safety and effective job execution. Developing such models and setting up operational safety paradigms and safety boundaries would help in the formulation of detailed procedures and better postulation of safety events. He mentioned the factors that must be considered for human behaviour analysis include psychological aspects, attributes from skill sets, HMI, and cybernetics. He spoke on the importance of HMI that is growing at a rapid pace and the necessity to associate these factors while developing HRP. He further suggested that by utilizing the concepts of *people-capability-maturity-model* (PCMM), which aims at indexing the organizational levels and thereby makes everyone a stakeholder in the organization functioning, a very high-end human trust-worthiness index can be achieved.

Dr. Lele started his talk by discussing the dependency of human performance being largely on human behaviour. One cannot understand human behaviour based on theoretical equations. The technological transformation happening in the present times is called the fourth industrial revolution. In this fourth industrial revolution, humans are looking at the applications of technologies and the pace at which the developments of technologies are happening is rapid on the human timeline of history. The talk instilled the seed in us to think about how reliability is going to shift places with the transforming technologies. He mentioned the role of disruptive technologies in society and how human reliability would be relevant at different levels of society while dealing with disruptive technologies. He talked about the building blocks of industry 4.0 and the possible change in the number of humans and robots and our necessity to understand human behaviour in such environments. He spoke about the possible transformation from machine monitoring to smart manufacturing and raised the question of human relevance in such a scenario. In a world where humans might not be there to err, human elements will still be relevant and there is a necessity to assess human reliability for disruptive technologies, which should be a part of industries of national importance.

Dr. Raj's talk discussed the transforming nature of machine and human interface. He mentioned that even though human error accounts for 90% of the accidents, the failure of an appropriate interface, design, or mechanism which creates confusion results in human error. In HRP, we should also focus on design and interface that can reduce human error. In the era of industry 4.0 with the rapid development of technology in various fields, there is a need to design and develop a human-machine interface that is practical, tactical, and effective. The talk gave an idea of risk from both social science and technologist's perspectives and risk management interface to reduce human error. He spoke on the need for user-centered design considering human factors. On the topic of reliability, he spoke about screening and training individuals who can adapt and effectively respond to the designs. His talk also addressed the issues of establishing an HRP and the steps that are required for the continuous evaluation process. He stressed the importance of communication in organizations. He mentioned the necessity of initial evaluation of employees as it reduces the likelihood for an unreliable applicant to be placed in HRP positions. He spoke about the main elements of HRP being supervisory review, medical assessment, management decision, and trust official review. The talk gave a complete layout of HRP on the people, threats involved, different stages of evaluation, and benefits of HRP. He spoke about training the people in HRP to identify, evaluate, and report any unusual behaviour. Continuous review of the staff

through management training and program implementation can provide an effective mechanism for a successful HRP.

Prof. Patnaik's talk focused on the computer science perspective of human reliability. He raised the issues of software failures and gave examples of accidents, where software had a role along with human error which resulted in accidents. He spoke about the challenge of maintaining complex systems and their functions. He mentioned cyber threats and the possible rise in such threats in the future and the necessity to deal with them. His talk discussed the challenges in developing software for different industries based on the requirements. He stressed the importance of developing human reliability analysis for the software development process to study the factors that result in mistakes during development. Accidents happen because of both software and human errors. It is possible to analyze different types of faults likely to be introduced by humans so that suitable testing strategies can be developed to detect such faults. Human reliability analysis and studies can thus be very effectively used in the software development process. He also focused on cognitive factors as one of the root causes of developmental defects and how understanding the cognitive mechanisms involved in software development can help us to gain a better knowledge of error mechanisms. Though human errors have been studied in safety-related critical systems, such as aviation and nuclear industries, software development may need different treatment.

Prof. Sai Baba's talk gave a view on the necessity of human reliability across different domains. He started the talk with the idea of scientific inquiry and the research and development perspective towards human reliability. According to Prof. Baba, HRP mostly focuses on safety and security. He said that apart from the major issues of safety, insider threat, and sabotage, HRP should also focus on factors that cause reduced productivity and quality. He discussed the environment that is created when every co-worker and employee is regarded as a threat and how this affects the procedures to implement HRP. He spoke about the changing face of the human-machine interface and the necessity to develop HRP accordingly. He highlighted the challenges in developing automated designs that affect a huge population and the reliability of individuals who are involved in the process. He stressed the importance of continuous evaluation and identifying the factors that make an individual unreliable. He discussed the importance of the environment of the individual and the role of the work environment and mentors that would influence an individual.

Behavioural Observation and Psychological Perspectives in Human Reliability Program was the theme of the talk by Dr. Stainback IV. Supervisors, co-workers, and peers are likely to be the most effective 'sensors' of aberrant or troubling human behaviour within the workplace. The establishment of a well-documented system through training for reporting such observations enables others to feel comfortable in reporting. An effective Behavioural Observation Program (BOP) helps improve the defense-in-depth provided by insider mitigation, physical security, and fitness for duty programs. The BOP focuses on personnel who have been authorized access to certain materials, information, and facilities deemed important and at high risk to the welfare of the company or national security. The BOP provides assurances that individuals, who are trained, to look out for certain unusual individual traits that may result in a risk to the company, national security, employees, or public health. Such

examples of these issues are drug, and alcohol use, mental health issues, unusual spending, foreign contacts, working odd hours, disregard for policies, fatigue, and depression. He suggested action points to be pursued which included developing BOP and associated training to inform the employee about the necessary expectations commensurate with a full HRP.

Dr. Stainback IV further talked about "the Importance of Ethical Behaviour in Human Reliability Program". Social norms within the workplace, as driven by anthropological culture, dictate certain behaviours generally accepted to ensure the product or services are being produced at the highest quality, without injury to the worker, at the lowest cost, and without harm to others including financial harm. Various countries around the world have different thresholds of ethical decision making. Within this presentation, lessons learned are shared of those who have taken advantage of their respective status and betrayed the trust of their peers, employees, and customers in facilities where employee trust and integrity are at the highest level. Greed is typically the motivator of such behaviours. Research has shown when people commit minor unethical behaviours, it is likely that they commit major unethical behaviours. Companies and government organizations, especially high-risk organizations, such as nuclear power plants, chemical processing facilities, and other facilities whereby commodities can lead to serious consequences, should pay close attention to ethical decision making and policies. He suggested action point to be pursued is to develop ethics policies and commensurate refresher training programs to deter such behaviours as these programs inform the employee the necessary expectations and associated consequences.

Dr. Clark, in his talk "Human Reliability Program: Initial and Continuing Evaluation Process" discussed about a system for initial and continuous evaluation of individuals certified in HRP positions to be considered important for the success of HRP. A permanent effort to improve the communications skills of inline and senior managers also affects the success, therefore the importance of communications must be emphasized. The initial evaluation is intended to reduce the likelihood that unreliable applicants will be placed in HRP positions. Continuous evaluation checks the information, including security concerns, relevant to the individual's suitability to perform HRP tasks securely and reliably. The supervisor's continuous evaluation is of utmost importance. The management system of processes and procedures enhances the ability to communicate effectively with staff. Maintaining positive employment standards and the role of leadership for the sustainable and the success of a program is extremely important. Reducing the risk of employing individuals who may not meet trustworthiness requirements strengthens the ability to maintain a secure workforce. The continuous review of staff through management training and program implementation should provide an effective mechanism for a successful HRP.

National Institute of Advanced Studies
Bengaluru, India

TEXAS A&M UNIVERSITY

First Meeting of the Core Group
on

Human Reliability Program in Industries of National Importance

October 15-17, 2019

National Institute of Advanced Studies (NIAS), Bengaluru

Jointly Organized by NIAS and Texas A&M University, USA

TEES
TEXAS A&M ENGINEERING EXPERIMENT STATION

NSSPI
CENTER FOR NUCLEAR SECURITY SCIENCE & POLICY INITIATIVES

Introduction

In continuation of the collaborative project between Texas A&M University and NIAS, the two institutions worked together to form a core working group to study and discuss the HRP in the context of industries in India. Accordingly, a core group was formed and the first discussion meeting of the core group on "Human Reliability Program (HRP) in Industries of National Importance" was conducted during October 15-17, 2019, at NIAS Bengaluru. This meeting was a follow up activity based on the recommendation from a previous discussion meeting on Human Reliability Program that was held in NIAS on April 24-26, 2019. The main objective of the meeting was to discuss among Indian experts the various elements of HRP and specific implementation needs in India given the Indian cultural and societal context. The meeting also aimed at identifying good practices in safety and security with respect to HRP and its implementation challenges. There were 22 participants at this core-group discussion meeting. One participant from the U.S. (Texas A&M University), three from the Indian Atomic Energy Regulatory Board (AERB), eight from the various units of the Indian Department of Atomic Energy (DAE), five from the Indian academia (Amity University, Indian Institute of Technology Bombay, Indian Institute of Technology Kharagpur, Jamia Milia Islamia Central University Delhi, and Loyola Institute of Business Administration Chennai), and five from two Indian non-DAE research centres (Institute for Defence Studies and Analyses Delhi and NIAS Bengaluru). The discussion meeting agenda included presentations and discussions on various aspects of HRP. The meeting concluded with a panel session and next steps discussion. The Panel Discussion Summary is in the later part of this document. A summary of the meeting and next steps on the engagement with NIAS on the HRP in India are also presented in this report.

First Meeting of the Core Group on Human Reliability Program in Industries of National Importance

AGENDA

October 15 (Tuesday), 2019

Time	Topic	Speaker
0900 – 0930	**Registration**	All
0930 – 1000	Welcome Speech Opening remarks and Meeting Objectives	Shailesh Nayak M Sai Baba Sunil S. Chirayath
1000 – 1015	Participant Introductions	
1015 – 1100	HRP challenges and Summary of April 2019 HRP Meeting	M Sai Baba
1100 – 1130	**Tea break**	All
1130 – 1215	HRP Elements: Evaluation and Continuous Evaluation, Monitoring (Unusual Behavior Observation), Ethical Behavior, Fitness for Duty	Sunil S. Chirayath
1215 – 1300	Human Reliability and Technology Disruption	Ajay Lele
1300 – 1400	**Lunch**	All
1400 – 1445	Human Reliability aspects in scale-up, deployment and standardization of new technologies the Chemical Industry	Anjan Ray
1445 – 1500	Human Reliability Improvement at NPPs	N Kanagalakshmi
1500 – 1530	**Tea Break**	All
1530 – 1610	Challenges in Human Reliability Analysis for PSA	Gopika Vinod
1530 – 1610	Human Factors in responding to design extended conditions in nuclear power plants	M Seshaiah
1610 – 1630	System's Approach to Accident Analysis	Ipshita Chowdhury
1630 – 1700	Discussion on Common HRP Elements in Critical Industry: Prepare Questions for Panel	All

First Meeting of the Core Group on Human Reliability Program in Industries of National Importance

AGENDA

October 16 (Wednesday), 2019

Time	Topic	Speaker
0930 – 1015	Barriers and Challenges in the development of a consolidated Human Reliability Program	Vivek Kant
1015 – 1100	Cognitive factors in Human Reliability	Manas K Mandal
1100 – 1130	**Tea break**	All
1130 – 1300	Case Studies Discussion on the HRP Benefits	Sunil S. Chirayath
1300 – 1400	**Lunch**	All
1400 – 1430	Relevance of Human Reliability Programme: The Role of Academic Institutions	Reshmi Kazi
1430 – 1500	Augmenting Human Reliability Programme employing Human Centric Design	Xavier Raj
1500 – 1530	**Tea Break**	All
1530 – 1615	Accident Causation: Role of Active and Latent Failures	Dinesh Kumar Shukla
1615 – 1700	Preparation of Questions for Panel Discussion	All

First Meeting of the Core Group on Human Reliability Program in Industries of National Importance

AGENDA

October 17 (Thursday), 2019

Time	Topic	Speaker
0900 – 0930	Preparation for Panel Discussion	
0930 - 1100	Perspective from experts	
0930 – 1000	Human reliability Program and educational institutions	KL Ramakumar
1000 – 1030	HRP aspects in Nuclear Industry in the framework of Industry 4.0	Kallol Roy
1030 – 1100	Safety and Security in Nuclear Industry, Importance of Good practices and Human Reliability	G Srinivasan
1100 - 1130	**Tea Break**	All
1130 - 1245	Panel Discussion on "HRP In Indian Context" Dinesh Kumar Shukla (Chairperson) KL Ramakumar Kallol Roy R. Satyanarayana Dinesh Kumar Srivastava G Srinivasan	*Coordination:* Sunil S. Chirayath and M Sai Baba
1245 – 1300	Concluding Discussions and Next Steps	*Coordinated by* Sunil S. Chirayath M Sai Baba
1300 – 1400	**Lunch**	All
1400 – 1700	Discussions amongst the participants	All

First Meeting of the Core Group on Human Reliability Programin Industries of National Importance

October 15-17, 2019.

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First Meeting of the Core Group on Human Reliability Program in Industries of National Importance

October 15-17, 2019.

Abstract of the talks and Biographies of the participants.

HRP challenges and Summary of April 2019 HRP Meeting

M Sai Baba
TV Raman Pai Chair Professor, NIAS

Human Reliability Program has different connotations, and strategies of implementation must meet challenges. The most important of them being how to factor in diversity and work culture. Effective Human Reliability Program depends on the effective interface with the technology and adopting the same. While it is essential that effective measures and practices to be put in place ensure safe operations, equally important to put in place are the methods of arriving at the process of identifying the transition. To explore the possibility of the lessons learnt from one industry to implement in other industry and weaving a common fabric for safe and reliable operations. The talk would touch upon these aspects briefly.

The summary of the discussions of the meeting held during April 2019 at NIAS would be given.

Prof. M. Sai Baba, Outstanding Scientist and formerly Director, Resources Management Group, Indira Gandhi Centre for Atomic Research and Senior Professor, Homi Bhabha National Institute. Presently holding the TV Raman Pai Chair Professor at National Institute of Advanced Studies. At NIAS he is currently working in the domains of Science and Risk Communication, Human Reliability Program and Understanding Ancient Indian Knowledge Systems for applying them for the holistic development of youth.

He did his postdoctoral work at Texas A&M University and was a Visiting Scientist at Research Centre, Julich, Germany. He has also spent time at Nuclear Research Centre (KFA), Julich as Guest Scientist under Indo-German Bilateral exchange program. He is conferred Doctor of Science (Honoris Causa) by Dr MGR University, Education and Research Institute.

Dr. M. Sai Baba has made significant contributions towards institution building and academic management and contributed in implementation of several high impact activities of relevance to Department of

Atomic Energy. He played a pivotal role in starting the BARC Training School at IGACR and was heading the same till the time of his superannuation.

Amongst others he is a member of: High-level committee on S&T Institutional & Human Capacity Building, constituted by DST and Expert Committee, UGC- SERO, Hyderabad, Constituted by UGC.

Talk 1:
Human Reliability Program (HRP) Elements: Evaluation and Continuous Evaluation, Monitoring (Unusual Behavior Observation), Ethical Behavior, Fitness for Duty

Sunil S. Chirayath
Associate Professor of Nuclear Engineering
& *Director, the Centre for Nuclear Security Science* & *Policy Initiatives, Texas A&M University, USA*

The HRP is a security and safety reliability program designed to ensure that individuals who occupy positions affording access to certain materials, facilities, and programs meet the highest standards of reliability and physical and mental suitability. This objective is accomplished through a system of continuous evaluation that identifies individuals whose judgment and reliability may be impaired by physical or mental/personality disorders, alcohol abuse, use of illegal drugs, the abuse of legal drugs or other substances, or any other condition or circumstance that may be of a security or safety concern. An HRP position affords the potential to significantly affect national security or cause unacceptable damage to a facility, institution, and programs. Before such nomination, the Manager or the HRP management official must analyze the risks the position poses for the particular operational program. If the analysis shows that more restrictive physical, administrative, or other controls could be implemented that would prevent the position from being designated an HRP position, those controls will be implemented if practical. A system for initial and continuous evaluation of individuals certified in HRP positions is considered important for the success of HRP. A permanent effort to improve communications skills of inline and senior managers also affects the success, therefore communications must be emphasized. Initial evaluation is intended to reduce the likelihood that unreliable applicants will be placed in HRP positions. Continuous evaluation checks the information, including security concerns, relevant to the individual's suitability to perform HRP tasks securely and reliably. Supervisor's continuous evaluation importance is needed. The management system of processes and procedures enhances the ability to communicate effectively with staff. Maintaining positive employment standards and the role of leadership for a sustainable program and success of a program is extremely important. The approach to initially reduce the potential for including an individual who may not meet trustworthiness requirements strengthens the ability to maintain a secure work force. The continuous review of staff through management training and program implementation should provide an effective mechanism for a successful HRP. Developing ethics policies and commensurate refresher training programs to inform the employee about the necessary expectations and associated consequences can be part of the

HRP. Another important element of HRP is developing a "Behavioral Observation Program" and corresponding training programs to inform the employee the necessary expectations commensurate with a full HRP. The presentation at the meeting will discuss HRP elements and its implementation roadmap.

Talk 2:
Case Studies Discussion on the Human Reliability Benefits

The data on HRP implementation is treated confidentially by the implementing facilities. However, in general the data suggests the importance and need for an HRP in critical industries. A set of anonymous data without referring to the facility names will be presented to inform the HRP meeting and panel discussion.

Prof. Chirayath is the Director of the Center for Nuclear Security Science & Policy Initiatives (NSSPI) at Texas A&M University with a joint appointment of Associate Professor in the Department of Nuclear Engineering. He holds a specially appointed Associate Professorship in the Tokyo Institute of Technology where he spends 3 months per year and also is an honorary professor in the Amity Institute Nuclear Science and Technology at Amity University. He is an adjunct Professor at the National Institute of Advanced Studies, Bengaluru, India. His B.Sc. (University of Calicut), M.Sc. (University of Calicut), and Ph.D. (University of Madras) degrees are in Physics. He also was a Bhabha Atomic Research Center Stipendiary Trainee for one year at Tarapur in India. Previous positions include: Scientific Assistant, Indian Atomic Energy Regulatory Board, Mumbai (1991 - 1998); Scientific Officer, Indian Atomic Energy Regulatory Board, Kalpakkam (1998 - 2007); Postdoctoral Research Associate, Texas A&M University (2007 - 2010); Research Scientist, Texas A&M University (2010 - 2014), Associate Director-NSSPI (2014-2015). He has more than 28 years of experience in Nuclear Science and Engineering research, education and training with specialization in nuclear safety, security and safeguards. He teaches courses on nuclear fuel cycle and nuclear material safeguards, nuclear security, nuclear non-proliferation, and Monte Carlo radiation transport. Research interests include safeguards approaches for nuclear fuel cycle, proliferation resistance quantification & analysis, nuclear forensics, nuclear security insider threat analysis, fast breeder reactor analysis and small modular reactor neutronics coupling with thermal hydraulics. In current position, manages and directs projects funded by USDHS, USDOE, USDOS, the IAEA and nuclear utility companies. Has conducted nuclear security educational programs in the U.S. and abroad for faculty and professionals. He has over 170 technical publications in referred journals (47) and peer reviewed (28) and other conference proceedings (99). He has supervised more than 34 MS thesis and PhD dissertation research of students (including 13 current students), most of them conducting research in the area of nuclear non-proliferation and neutronics. He has also supervised 5 postdoctoral research associates in the nuclear non-proliferation and nuclear security subject area.

Human Reliability and Technology Disruption

Ajey Vishwanath Lele
Senior Fellow, Institute for Defence Studies Analyses, New Delhi

For many centuries, the human society has expressed high attention for performance or failure in practically all areas of their interest. It is well understood that the human error has been a cause for certain failures in various human endeavours for long. Particularly, with the beginning of industrialization, a period of development began that transformed largely rural, agrarian societies into industrialized societies. Industry is impacting human lives for many centuries now, from the days of coal mining and the invention of railroads to the invention of the internet and humans simplifying the mystery of human DNA. This presentation looks at the issues concerning the human reliability aspects in context of the fourth industrial revolution. Particularly, with the focus on the sectors like aerospace and defence. Over the years it has been realised that various human factors including the human errors are playing an important role, both positively and negatively towards impacting the performance of these industrial sectors. The challenges are more in case of aerospace and defence sectors owing to the nature of technological investments and also since they are the strategic industry sectors. Hence, there could be national security connections too, in respect of HRP for these sectors.

Dr. Ajey Lele, is currently working as a Senior Fellow at the Institute for Defence Studies and Analyses (IDSA), New Delhi. He started his professional career as an Indian Air Force Officer and took early retirement from the services to peruse his academic interests. His specific areas of research Space Security and Strategic Technologies. He has various publications against his name and his important book publications include Strategic Technologies for the Military (Sage, 2008) and Asian Space Race: Rhetoric or Reality (Springer, 2013). Disruptive Technologies for the Militaries and Security (Springer, 2019).

Human Reliability aspects in scale-up, deployment and standardization of new technologies the Chemical Industry

Anjan Ray
Director, Indian Institute of Petroleum, Dehradun

The chemical industry, while indispensable for everyday living, requires a high degree of human reliability to the inherent nature of hazardous materials handled and the processes involved in their conversion to intermediates and useful products. Yet, a large number of Indian chemical producers are from micro, small and medium scale enterprises. Based on the risks assessed, a compelling case can be made for emphasis on Human Reliability Analysis and development of relevant training and skill development programs in the Indian Chemicals sector.

Anjan Ray received his Doctorate in Chemistry from the University of Pennsylvania under the guidance of Nobel Laureate Prof. Alan MacDiarmid. He then moved to the chemical industry and worked for over 25 year across functions ranging from Quality Control, Technical Service, R&D and Marketing to General Management, Mergers & Acquisitions and Corporate Strategy. His professional interests have spanned fields as diverse as surfactants, oleochemicals, paints, adhesives, textiles, cosmetics, pharmaceuticals, water treatment, energy efficiency, biofuels and renewable energy policy. Currently, he holds the position of Director, CSIR-Indian Institute of Petroleum, Dehradun. Apart from his professional career in chemical technology, Dr Ray has had an active interest in media, education, heritage and environmental conservation for over 3 decades.

Human Reliability Improvement at NPPs

N. Kanagalakshmi
Engineer-In-Charge, Fire & Industrial Safety, Scientific Officer (F)
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Researchers from different fields of science and engineering have developed a theory of incident causation which will help to identify, isolate and ultimately remove the factors that contribute to or cause accidents. According to W.H. Heinrich (1931), who developed the so-called domino theory, 88% of all incidents are caused by unsafe acts of people, 10% by unsafe actions and 2% by "acts of God". Since the unsafe acts are the leading causation factor, the human contribution is prevailing. The underlying contributory causes (Latent & Active failures) were identified and are mainly due to human error due to various factors. Due to the sophisticated design and inherent complexity of Nuclear Power plants, it is felt that the human error is playing a predominant role in safe operation of plant. So, the cognitive based model for fast diagnosis, decision making and action were suggested for crew performance to increase the human reliability. Also, the old view and new views on human errors were highlighted. The suggestions/ feedbacks were listed out at the end of the presentation.

Ms. N. Kanagalakshmi is having 15 years of work experience and presently working as an Engineer-In-charge, Fire & Industrial Safety Section and designated as a Fire Protection Engineer. She is basically a Mechanical Engineer and completed her Master's Degree in Industrial Safety. She is taking care of the fire and industrial aspects at Prototype Fast Breeder Reactor (PFBR). She is capable of carrying out various analysis and legal clearances such as Legal statutes related to HSE, Safety Audits, Risk Assessments, HAZOP, FMEA, PHA, JHA, FTA, ETA, TA, Root cause Analysis Techniques, Accident Investigation techniques, Fire Probabilistic safety Analysis, Lead Auditor-OHSAS 18001, ISO 14001, Ergonomic assessments, Workplace analysis, Safety Trainings, Fire Management, Fire Hazard Analysis, Fire Audit, Vulnerability Analysis & Disaster Management Plan, Environment Management, Environment Clearance & approvals, conducting Emergency evacuation drills at offices, high rise buildings, schools and hospitals. She has presented several papers in national and international conferences and contributed for the monograph publications jointly with AERB.

Challenges in Human Reliability Analysis for PSA

Gopika Vinod
Head, Probability Safety Section, Reactor Safety Division, Scientific Officer (H)
Bhabha Atomic Research Centre (BARC), Trombay, Mumbai

Human performance is essential for the safe and reliable operation of complex systems. Human error has been documented as the primary contributor to many of the accidents in the nuclear industry. Therefore, the assessment of system safety must address the human element, considering how it may contribute to the safety as well as risk. Human error may occur in any phase of the design, manufacturing, construction, and operation of a complex system. Human reliability analysis (HRA) is a well-recognized and accepted methodology to identify such human errors, quantify their likelihood in terms of Human Error Probabilities (HEPs). Humans tend to perform/behave differently under different circumstances. Therefore, the relationship between the human performance and the circumstances needs to be understood. This relation is well captured by the Human Factors (HFs) or the Performance Shaping Factors (PSFs). Different HRA methods deal with a different set of HFs. Since all these methods are in practice from early nineties and still used in estimating human error probability in Probabilistic Safety Assessment (PSA), highlights the urgency to devote appropriate modification of these first-generation methods to cater to highly human action dependent scenarios in Level-2 PSA, shutdown PSA, extreme events PSA, etc. This is complicated by the lack of operating data in such situations. Virtual Simulations, being cost effective, can be considered as source of generating human error data. The latest technology is digital and is replacing the analogue systems, which adds another dimension in the estimation of human factors. The presentation will highlight these challenges and recent research directions in human reliability analysis from a safety perspective.

Dr. Gopika Vinod joined with Reactor Safety Division of Bhabha atomic Research Centre as a Scientific Officer from 37th batch of Training school after completing her graduation in Computer engineering. After that she got her doctoral degree in Reliability Engineering from Indian Institute of Technology, Bombay. She has also been post-doctoral fellow at Steinbies Advanced Risk Technologies, Germany. Currently she is heading the Probabilistic Safety Section of Reactor Safety Division of BARC. She also holds the position of Professor with Homi Bhabha National Institute. She has been actively involved in Reliability, Safety and Risk analysis of Indian Nuclear Power Plants and on the development of Reliability based Operator Support Systems for Indian Nuclear Power Plants. Her other areas of research activities include reliability of computer-based systems, dynamic reliability analysis, etc. Member of the editorial committee, referee in international journal.

Human Factors in Responding to Design Extended Conditions in Nuclear Power Plants

Seshaiah Mupparaju
Training Superintendent, Scientific Officer(H)
National Power Corporation of India Limited (NPCIL), Kaiga

This presentation describes human factors that are relevant in severe accident situations and their effective handling in Nuclear Power Plants. Human Factors include the capabilities of plant personnel to contribute to unconventional measures to mitigate plant vulnerabilities, including the behaviour and reliability of personnel under adverse environmental conditions that pose risks to the health or even the life of plant personnel. Human factors are part of design and normal operation as well, and training on these factors is part of the existing training to the operating staff. However due to adverse conditions expected during beyond design basis situations, human factors under such conditions have to be dealt at different level. This was quite evident in Fukushima accident. The workers faced multiple challenges and hazards. In India also such a situation was encountered when MAPS was affected by the tsunami in 2004. Human factors are the factors that influence human performance as it relates to the safety of a nuclear facility or activity over all phases, including design, construction, commissioning, operation, maintenance, and decommissioning. Human factors under design and normal operation include factors such as ergonomics, man machine interface, communication, teamwork etc. In accident domain these factors are at different levels and in severe accident conditions they become further intense for safe handling of the event. Accident management involves an overall structure, which clearly delineates responsibilities and any transfer of responsibilities during the development of an accident, is the essential starting point.

Mr. M. Seshaiah is a graduate in Electronics & Communications Engineering with distinction in the year 1990 from Andhra University, Andhra Pradesh. He joined Nuclear Power Corporation of India Limited (NPCIL)in the year 1990. He has 28 years of experience in NPCIL. He is an expert in state of art reactor control systems like regulation and protection systems, Computer based process control systems, Computerized operator information systems, advanced access control systems and nuclear security systems and successfully commissioned these systems in Narora Atomic Power Station (Uttar Pradesh) and Kaiga Generating Station-1&2 (Karnataka). During his tenure as Head, Control & Instrumentation at KGS-1&2, the Kaiga units had created new records of continuous operation. As a chairman of Public Awareness Campaign (PAC), he played an instrumental role in educating and improving awareness about the Nuclear Technologies. By recognition of his excellent contributions and self-motivation, he had been awarded NPCIL Special contribution award and Group Achievement Award by the Chairman & Managing Director under NPCIL High Performers Scheme.

System's Approach to Accident Analysis

Ipshita Chowdhury
Postdoctoral Research Associate, National Institute of Advanced Studies

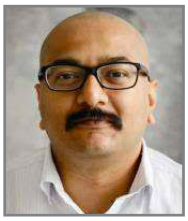
Loss of situation awareness by individual operators (e.g. pilots, drivers, control room operators) is commonly cited as a causal factor in accident investigation reports. This is despite the fact that it is now widely accepted that accidents are a systems phenomenon caused by multiple, interacting factors across overall systems. This work argues that situation awareness is a key safety science concept that can be used to understand accident causation; however, only when it is considered at a systems level that is only when accident investigators assess the awareness held by the overall system and not the awareness held only by individuals. This will be demonstrated through a distributed situation awareness analysis of the Air France 447 crash. The analysis will show how it is the overall system comprising air- crew, cockpit systems, airplane etc., that lose situational awareness and not the individual pilots alone.

Ipshita is a PhD in Cognitive Ergonomics from Heriot-Watt University, Edinburgh (UK). Following her PhD, she has worked on several projects such as developing a head up display for car drivers funded by Faurecia, assessing cognitive workload in highly automated vehicles and intention to cross red lights using theory of planned behaviour. Ipshita's research focuses on understanding and optimizing human, team, organizational and system performance through the application of Human Factors theory and methods. Ipshita's current research interests include complexity and sociotechnical systems theory and safety, the development and application of accident prediction, analysis, and prevention methods.

Barriers and Challenges in the development of a consolidated Human Reliability Program

Vivek Kant
Assistant Professor, IDC School of Design, Indian Institute of Technology Bombay

With a rapidly globalizing India, the role of humans in technological setups are addressed in a multitude of ways. However, in the current institutional setup, there is a need for a consolidated and joint approach to the problem of human factors in technological systems. The aim of my presentation will be to provide a set of disparate images that are often used for construing people in technological systems. Further, I will present barriers and challenges in the development of a coherent Human Reliability program. I will conclude with a way forward in terms of a conjoined understanding of humans in a variety of technological application sectors that will serve as the steps towards a more comprehensive construal of humans in technological systems.



Vivek Kant is currently employed as an Assistant Professor at the Industrial Design Centre (IDC School of Design), Indian Institute of Technology Bombay (IDC, IITB). He is cross-trained in both engineering and cognitive/behavioral sciences. He works on the problem of requirements analysis, along with interaction design and design for humans, in complex systems. His broader research interests are human factors, human computer interaction, history and philosophy of engineering, and sociotechnical systems.

Cognitive Factors in HRP

Manas K Mandal
Distinguished Visiting Professor, Department of Humanities and Social Sciences, Indian Institute of Technology, Kharagpur

Understanding of HRP issues across industries of national importance calls for discussions related to several issues of psychological relevance which include: (a) mental/personality or physical disorder that impairs performance, (b) indication of deceitful behaviour, attempted or threatened destruction of property or life, (c) suicidal tendencies or attempted suicide, (d) inability to deal with stress, or the appearance of being under unusual stress, (e) failure to comply with work directives; violation of safety or security procedures, (f) hostility or aggression toward fellow workers or authority; uncontrolled anger, (g) significant behavioural changes, absenteeism, depression, etc. These issues gain more importance since such behaviours are more affective in nature and has an intent (or motivation) behind. The probability of failure in high-risk jobs are, however, not always limited to 'affect or intent'. Human actuations that require a cognitive process of understanding and decision making are also prone to errors which significantly reduces reliability of performance in industries of national importance. The present deliberation will highlight these 'unintended' errors which are embedded into our cognitive system. It proposed therefore to create two interdependent psychometric profiles, cognitive & affective, during personnel selection to determine the suitability of assigned job. The process will allow human actions to remain within the tolerances established by the system requirement.

Dr. Manas K Mandal is currently serving as Distinguished Visiting Professor at Indian Institute of Technology - Kharagpur. He was formerly a Distinguished Scientist and Director-General - Life sciences in DRDO [2013-2016]. Prior to this, he was Chief Controller R&D (Life Sciences), DRDO. He was also the Director, Defence Institute of Psychological Research for about nine years. Mandal and his team were given away 'Agni Award for Excellence in self-reliance' for the contribution towards the development of 'Computerized Pilot Selection System' for Air Force. For his overall contribution to psychological sciences, he was elected as the Fellow of National Association of Psychology in India in 2012; and for his contribution to Military Psychology, he was given away the 'Technology Leadership Award' by the Defence Minister of India and the 'Scientist of the Year' award by the Prime Minister of India in 2006 (DRDO). Dr. Mandal specializes in the areas of Neuropsychology and Cognitive Sciences. He has to his credit 12 books, over 100 research papers in international and

Indian journals of high repute. These researches are cited in more than 300 international journals and books with over 2000 citations.

Relevance of Human Reliability Program in the Defence and the Role of Academic Institutions

Dr. Reshmi Kazi
Associate Professor, Nelson Mandela Centre for Peace and Conflict Resolution, Jamia Milia Islamia, New Delhi

A Human Reliability Programme (HRP) is primarily aimed to certify that individuals manning sensitive positions with access to sensitive materials, facilities, and agendas meet the highest standards of reliability, trustworthiness and physical and mental aptness and is a principal requirement in all critical infrastructure including nuclear industries. Moreover, with the increasing lethality of terrorism attacks coupled with rapid spread of information technology, contemporary times mandates an increasing necessity of effective human reliability programmes. Besides, the risk emanating from whistle-blowers needs to be factored into while dealing with the necessity of effective human reliability programmes. The incidents of leaks of strategic information bears testimony that there is always possibility of high vulnerability of sabotage or unauthorised access to or use of sensitive materials, information and systems of a nuclear facility. A rigorous HRP practice to be put in place ensuring continued motivation of the employees involved in it.

What role can academic institutions play in enhancing the importance of HRP? The academic institutions have a critical role to play in this regard. It is an undeniable fact that there is scarce domestic narrative on critical issues like HRP and its relevance to sensitive infrastructure. The academic community has a significant responsibility to develop a narrative on India's critical requirements premised upon a framework that pertains to our potential threats and vulnerabilities. For this purpose, academic institutions must be more forthcoming with organizing various workshops, symposiums, seminars and conferences to generate awareness and interest in this critical domain.

Reshmi Kazi is an Associate Professor at Jamia Milia Islamia, where she specializes in South Asian politics and Arms Control and Disarmament. She was previously an Associate Fellow at the Institute for Defence Studies and Analyses (IDSA). Her latest publication includes co-edited volume on India in Global Nuclear Governance.

Augmenting Human Reliability Program leveraging Human Centered Design

Prof. A. Xavier Raj
Chief Executive, Loyola Inclusive Innovation Impact Centre (L3iC), Chennai and Adjunct Faculty, NIAS

The increase in number of nuclear / coal-powered plants, technological advancement, and widening of specialization has increased the diversity of workforce. Individuals vary along the spectrum of skillsets, aptitudes, and resilience. Advancement in technology, data science, digitalization and automation, in 21st Century, has contributed to automation related complexity. The requirement of personnel hiring, training, retaining and motivating has assumed new significance, in this emerging scenario. In India, with likely reliance on nuclear energy, number of personnel to be deployed has increased manifold. India offers an interesting mix of centralization, corporatization and private sector involvement. This country specific complexity needs to be considered in the context of sustaining a credible human reliability in this sector. It is now possible to augment machines, men and the interface with user at the center of designing. Human / User centered design contextualizes applying a holistic frame to design every component, operations, protocols or metrics for reliability, be it machine or humans. It is pertinent to leverage experience elsewhere to design appropriate user centered options considering social, cultural, psychological or anthropometrics. The urgent requirement is to create a space for collaboration between India and stakeholders in other countries, to launch a systematic process to utilize advancements in Human Reliability Programme globally with the science of human / user centered designs. This paper discusses these three aspects: 1. Uniqueness of Indian Situation; 2. Contextualization of Human Reliability Program in this Indian Context; and 3. Importance of User Centered Design in this process of customization.

Dr. A. Xavier Raj, an experienced Anthropologist, Development Sector Specialist and Human Centred Design Proponent, is Chief Executive at Loyola Inclusive Innovation Impact Centre (L3iC), Chennai. He is also an Adjunct Faculty (Honorary Position) in National Institute of Advanced Studies (NIAS), IISc. Campus (Bengaluru). Earlier he served as Professor of Entrepreneurship Management and Chairperson of C.K. Prahalad Centre (LIBA). Xavier has 17 years of corporate experience as business head in global market research and consulting firms: with Blackstone MarketFacts (US firm), Synovate (a British conglomerate), and Ipsos (French company). During this tenure at MNCs established two profit generating specialist divisions. Xavier's core expertise includes Strategic Consulting (multi country), Human Centred Design, UX, Humanitarian Assistance, Design Thinking and Inclusive Innovation. As an Entrepreneur founded TSP Consultancy Services Pvt. Ltd., Serendip Boutique, TechLoyola Organics, YX Infra and GTEC, Canada. Currently mentoring 10+ start-ups at L3iC. Taught in University of Madras – Social, Cultural, Applied, Ecological and Developmental Anthropology / Sociology, Culture and Management and Business Sustainability.

Accident Causation: Role of Active & Latent Failures

Dinesh Kumar Shukla
Executive Director of Atomic Energy Regulatory Board (AERB) and the Chairman of Safety Review Committee for Operating Plants (SARCOP), Atomic Energy Regulatory Board, Mumbai, India

High hazard installations such as nuclear power plant employ Defense in Depth (DID) philosophy to reduce the likelihood of accidents. These may include hard defenses like engineered barriers or soft defenses such as operating procedures and administrative controls. According to Swiss cheese model, these defenses have holes which are dynamic in space and time. When these holes in the different layers transitorily line up, they provide a trajectory for accident to happen. According to James Reason, these holes in the defenses arise for two reasons: (i) active failures and (ii) latent conditions/failures. Active failures are the unsafe acts committed by people who are at the sharp end of man-machine interface. Unsafe act can be due to various forms of human errors i.e. unintended actions such as slips or lapses which are due to attentional or memory failures and intended actions such as rule or knowledge-based mistakes or may be due to deliberate violations of safety norms. Such behaviour which gets translated into unsafe act while performing the job in turn depends on various cognitive human factors such as emotions, perceptions, psychological condition, physiological state, group characteristics, work environment etc.

Latent conditions/failures are the 'resident pathogens' which remain within the system. These arise from the strategic/tactical decisions of the designers, constructors, managers and maintainers. They may either provoke conditions in the shop floor such as time pressure, understaffing, inadequate equipment or may lie dormant within the system for a long time until they are revealed by internal audit, regulator or by triggering an accident/event.

Generally, most of accident investigations stop at identifying 'human error' as the root cause. However, there is a need to 'lift the veil' to understand the actual causal factor of the accident i.e. active failures or latent condition/failure. While specific forms of active failures are hard to foresee, latent conditions can be identified and remedied well in advance by a well-developed safety management system addressing HOT factors.

Mr. Dinesh Kumar Shukla is a graduate mechanical engineer, with over 37 years of experience in operation and regulation of nuclear and radiation facilities. At present he is serving in Atomic Energy Regulatory Board (AERB) as Distinguished Scientist, Executive Director & Chairman of Safety Review Committee for Operating Plants (SARCOP) and an ex-officio Member of the Board. Before joining AERB, Mr. Shukla had served BARC for 33 years in various capacities, last being as Head, Reactor Operations Division (ROD). He has been associated with several committees of AERB and BARC Safety Council (BSC) for the design and operational safety review of PHWRs, LWRs, reprocessing plants and radioactive waste management facilities. He was a member of the Management Committee for Board of Radiation & Isotope Technology (BRIT) and also of the Radioisotopes, Radiation Technology and Application Committee (RTAC) of the Board of Research in Nuclear Sciences (BRNS).

Mr. Shukla has provided consultancy to IAEA on matters related to safety of research and power reactors, document preparation and for preparation of program for various IAEA international conferences. He has been associated with review meetings of Convention on Nuclear Safety as part of Indian delegation. He represents India in meetings of OECD-NEA committees (CNRA&CSNI), MDEP Senior Technical Committee, VVER forum and in bilateral meetings with regulatory bodies of other countries.

Human Reliability Program and educational institutions

K.L. Ramakumar
Former Head, Nuclear Controls & Planning Wing, Department of Atomic Energy and former Director, Bhabha Atomic Research Centre, Mumbai

Human reliability assessment (HRA) involves the use of qualitative and quantitative methods to assess the human contribution to risk. There are many and varied methods available for HRA. A continually evolving discipline, human reliability assessment (HRA) has elements of controversy from the definition of terms to the application of appropriate methods for the representation of human failure probability. The idea that human error is a random event is falling out of favour and the concept that humans can be set up to fail or succeed depending on context is gaining credibility. To improve human reliability, the causes of human errors should be identified, and the probability of human errors should be quantified. Analysis of human error is very case-specific; the context of the field should be considered. Human Reliability (to describe human performance) is widely used in fields requiring high standard of safety, such as aviation, petroleum and chemical process and nuclear industries. It is surprising that not much attention is being given to assess this important attribute in educational and research institutions. The first stepping stone in professional ladder starts with individuals in educational and research institutions. While the factors contributing to human factors differ very large, there could be some common thread which could be taken into consideration in assessing the human reliability which could also become quite handy in extending the assessment of that individual in future assignments. In the opinion of the author, identifying the negative attributes of individuals and addressing them is more critical than resorting to assessment tasks.

In the present talk, an attempt is made to explain these factors with illustrations in educational and research institutions.

Dr. K.L. Ramakumar has superannuated from the Department of Atomic Energy (DAE), Government of India in 2016 after serving the Department for more than 40 years in different capacities. Before superannuation he was Head, Nuclear Controls & Planning Wing (NCPW) in DAE and also Director, Radiochemistry & Isotope Group in Bhabha Atomic Research Centre, Mumbai. His expertise in the field of nuclear technology encompasses all the stages of nuclear fuel cycle, nuclear safeguards, nuclear safety and nuclear security. As Head, NCPW Dr. Ramakumar is responsible for activities and programmes of International collaborations and Safeguards Division (ICSD), Safety

and Security Studies Division (SSSD), Institutional Collaborations and Programmes Division (ICPD), External Relations Division (ERD) and Nuclear Law Division (NLD). In 2007, he organised a three-week course on Nuclear Law under the auspices of Homi Bhabha National Institute.

In addition to his scientific and technical publications, Dr. Ramakumar also delivered talks on policy related topics in: Nuclear safeguards and India's safeguards agreement. Nuclear safety and nuclear security, Nuclear energy the inevitable option R&D in India: a paradoxical situation, Nuclear liability. Other presentations of Dr. Ramakumar include subjects on nuclear safeguards as a powerful tool for ensuring nuclear safety and security, nuclear forensics, nuclear security: National requirements in the context of global governance. He was member of The Standing Advisory Group on Safeguards Implementation (SAGSI), IAEA from 2011-2016 and from 2016 is serving as member of Advisory Group on Nuclear Security (ADSEC), IAEA. He had also participated in two International conferences organised by IDSA in collaboration with Indian Pugwash Society in 2014 and another with PRIO in 2015 and delivered talks. He participated in the high-Level Fissile Material Cut-Off Treaty Experts Preparatory Group meeting held in Geneva during May-June 2018, and in the meeting of Group of Government Experts to discuss various of aspects of Nuclear Disarmament Verification, again in Geneva.

HRP aspects in Nuclear Industry in the framework of Industry 4.0

Kallol Roy
Chairman and Managing Director, Bharatiya Nabhikiya Vidyut Nigam (BHAVINI), Kalpakkam

The Human Reliability Program (HRP) in Nuclear Industry, encompasses the construction and equipment erection phase, followed by the Operation and Maintenance phase. A subsequent phase of plant aging management and refurbishing for plant life extension (which occurs after typically more than two to three decades of plant operation and necessitates certain *Systems, Structures* & *Equipment* (SSEs) to remain operational, while certain other SSEs undergo modification or replacement), again requires different levels of skill-sets and may necessitate HRP models different from the normal. While, individuals trained in typical civil construction & heavy-equipment erection of any large industrial or infrastructure development projects, may be adequate for the *Nuclear Power Plant* (NPP) construction phase, the *Operation* & *Maintenance* (O&M) phase of any NPP necessarily requires specialized and focused training and skill-set development and subsequent refurbishing phase, would need a team of personnel comprising of both infrastructure development skill-sets, along with licensed man-power of the specific NPP. However, notwithstanding the above phase-wise HRP requirements, in the present framework of Industry 4.0 there is a definite need for augmenting the earlier skill-set development programs, to utilize the automated and *Artificial Intelligence* (AI) based *Human-Machine Interface* (HMI) & *Cybernetics* pertaining to (a) *mechanical handling equipment,* (b) *automated machinery for batch processing, (c) interactive control rooms for process monitoring* & *surveillance* and (d) *virtual reality* (VR) or *augmented reality* (AR) based systems facilitating mock-up trials for SSE maintenance & upgrades.

Further to the above, there appears to be a paradigm shift in societal thinking, on possibilities of rapid learning and useful skill developments, through micro-training-programs, which would enable individuals to rapidly acquire specialized skill-sets, without having to go through long and arduous formal educational programs and thereby attaining early economic/ financial independence. This shift in societal thought-process is essentially owing to increased utilization of AI-based systems which are rapidly automating a number of conventional manual and human oriented processes & thereby rendering certain traditional skill-sets as redundant and at the same time creating a requirement for a different scale of skill-sets towards increased knowledge of handling AI devices and cybernetics. Hence, with regards to Nuclear Industry, an effective HRP program, within the growing framework of Industry 4.0, would thus require augmentation of knowledge/skill of personnel in the areas of computer-interface & AI, along with need-based domain expertise. The skill-set requirements could be further apportioned, so as to utilize personnel with focused and intense knowledge on specifics, by effective partitioning of major activities into many more segments/partitions than were required by traditional skill levels and thereby employ different &/or multiple teams for their execution.

An assessment of the impact of *Industry 4.0*, on the HRP for NPPs, hence requires a specialized study. The need to develop effective VR & AR based models for all SSEs, enabling *virtual walk-throughs* & *mock-up trials* and training of personnel on such platforms, are present-day requirements having the potential to improve the "*HRP-quotient*" significantly. However, the challenge lies in integrating the design details, manufacturing data & domain knowledge of all SSEs (which may usually remain NPP specific), along with the AI domain experts & tools, together with concepts of layered & need-based training program for personnel or teams. Further, there is a need to integrate the paradigm of *Big-Data Analytics* & *Bayesian Forecasting* as comprehensive human-plant interface, for enhancement of total plant safety and performance optimization along with the perspectives of technology growth forecast and the associated need for advanced training to personnel, for tweaking the HRP in order to keep pace with the dynamics of *Industry 4.0*.

Dr. Kallol Roy, is from the 28th batch of BARC training school and has received his B.Tech (Electrical) from NIT-Calicut, M.Tech (Electronics Design) from CEDT, IISC-Bangalore and a PhD (Fault Diagnostics) from Systems & Control Dept. IIT-Bombay. He was also a Post-Doc Fellow at the University of Alberta (Canada). Prior to his assumption of the present position as CMD, BHAVINI, he was in charge of total maintenance management, ageing management & refurbishing of all the research-reactors at BARC and also commissioning of new research & test facilities. He had also served in many AERB & BARC safety committees, BRNS committees and was also a Professor of HBNI. His specializations are in Total Plant Maintenance Management, System Fault Diagnostics, Uncertainty Estimation & Modeling in Instrumentation & Measurement Systems and EMI/EMC Modeling in Computational Electromagnetics framework. Presently, apart from his regular assignments, as CMD BHAVINI, Dr. Roy continues to pursue studies on application of Bayesian Estimation techniques for Project Scheduling & Technology Forecasting and Data Analytics for Plant Performance Optimization.

Safety and Security in Nuclear Industry, Importance of Good practices and Human Reliability.

G.R. Srinivasan
Former Vice Chairman, AERB

The talk consists of two parts. The first part includes a quick summary of HR (Human Reliability) in nuclear industry and its Regulatory control. The second part includes suggested areas to follow up in future deliberations. the two-fold approach of HR in nuclear is explained. Difficulties in Regulatory control of HR aspects are brought out. How they are taken care of by Regulatory bodies are described. Many other HR related issues in Nuclear are discussed. Eight different areas for future deliberations in HR are described. A few of these areas are procedure for HR audit, Performance indicators for HR, ingredients of achieving good HR, etc.

G R Srinivasan has Over 50 years of experience in Nuclear Industry, 42 years in Department of Atomic Energy, 5 years as Chairman of six committees of Atomic Energy Regulatory Board (AERB) and 7 years in GMR infrastructure. He retired as Distinguished Scientist. He held various positions, the last three being Director (Projects) in Nuclear Power Corporation of India ltd., Vice Chairman, AERB and Advisor Nuclear Power business in GMR infra. GR Srinivasan has attended two Advisory Group Meeting of International Atomic Energy agency (IAEA) on HR, Chairing one of them.

R Satyanarayana
Site Director, Kaiga, Nuclear Power Corporation of India Limited

Mr. R. Satyanarayana is a graduate in Electronics & Communications Engineering in the year 1983 from Andhra University, Andhra Pradesh. After completion of training at Baba Atomic Research Centre (BARC) in 1985, he joined Nuclear Power Board and later in 1987 Nuclear Power Corporation of India Limited (NPCIL). He has 34 years of experience in NPCIL, a larger organization under DAE in the field of construction, commissioning, maintenance, production and management in different Indian nuclear power plants. He has abundant exposure and experience at a senior level management position in the organization. He is an expert in reactor control systems; Microprocessor based computer systems, Computerized Data acquisition systems and successfully commissioned these systems in Narora Atomic Power Station (Uttar Pradesh) and Kaiga Generating Station-1&2. He has vast experience in the fields of maintenance, engineering services & plant management. During his tenure as Maintenance Superintendent at KGS, the Kaiga units had created new records of continuous operation. Based on his commendable performance, he was deputed to the 'World Association of Nuclear Operators (WANO), Tokyo, Japan. In acknowledgement with his efforts and commitment, he was elevated to the position of Station Director, Madras Atomic Power Station (MAPS) in January 2016. During his tenure, MAPS-2 recorded continuous operation of 512 days in FY 2018-19, first ever feat achieved in the history of

MAPS. Mr. Satyanarayana is an Outstanding Scientist and presently functioning as Site Director, Kaiga Site since December 2018. Since then, he is leading the team in working towards obtaining early clearance from various authorities to quick start construction of Kaiga-5&6. He played an instrumental role in Corporate Social Responsibility (CSR) programs and public outreach activities in the areas of education, health and infrastructure development in the surroundings, involving the external stakeholders and the neighbourhood communities as part of the corporate endeavours. Various CSR programs helped in improving the facilities and standard of living of the public in the surrounding neighbourhood. He is a leader with vision and an inspiring mentor for the younger generation scientists who join the Department of Atomic Energy. In short, he is an asset to the Department of Atomic Energy and Nuclear Power Corporation of India Limited.

Dinesh Kumar Srivastava
Homi Bhabha Cahir Professor, National Institute of Advanced Studies

Dr. Dinesh Kumar Srivastava is currently holding the Homi Bhabha Chair Professor at National Institute of Advanced Studies. Formerly he was a DAE Raja Ramanna Fellow & Former Director & Distinguished Scientist and Director, Variable Energy Cyclotron Centre, Kolkata. He is a Senior Professor, Homi Bhabha National Institute & Honorary Professor, Amity University, NOIDA. He Joined Bhabha Atomic Research Centre, Mumbai in 1971 as a Scientific Office and moved to Variable Energy Cyclotron Centre Kolkata in 1979, from where he retired as Director in 2016. He has held visiting positions in Germany, USA, Canada, and South Africa for various durations and is a Fellow of National Academy of Sciences, India and Indian National Science Academy. His present field of specialization is electromagnetic and heavy flavour probes of Quark Gluon Plasma, a matter which filled the entire universe at a few microseconds after the Big Bang. He has more than 150 papers and received several national and international awards for his research and academic activities. He has passion for popular writing and has several books to his credit.

V Magesh Mari Raj
Scientific Officer (E), Turbine Plant, BHAVINI

Mr. V. Magesh Mari Raj is basically a mechanical engineer having more than 15 of years of experience in procurement, erection and commissioning of power plant equipment. He did his B.E(Mech) from Madurai Kamaraj University in the year 1999 and did his Master of Engineering (Thermal Plant Engineering) from Bharathidasan University in the year 2002. Presently he is working as scientific officer/E at Bharatiya Nabhikiya Vidyut Nigam Limited, Kalpakkam and completely involved in the steam water system package of PFBR Project. He is also working for Probabilistic Safety Assessment of PFBR. Prior to join BHAVINI, he was working as engineer at Tata Projects Limited, Hyderabad. He has been recipient of Senior Research Fellowship from Safety Research Institute, Atomic Energy Regulatory Board (Year 2004 – 2005) and Senior Project Fellowship from Central Electro

Chemical Research Institute, CSIR (Year 2002). He is certified welding technologist from IIW, Kolkata. He is member of professional bodies such as Indian society of non-destructive testing and Society for Reliability and Safety, India. Apart from hardcore engineering, his pursuit of interest is ancient wisdom, Tamil literature especially Thirukural, Mudras and Yoga.

Dr. D. K. Mohapatra
Scientific Officer (H), Head, Reactor & Radiological Safety Section,
Safety Research Institute, Atomic Energy Regulatory Board (AERB), IGCAR Campus, Kalpakkam

Dr. D. K. Mohapatra started his career as a Scientific Officer in the Nuclear Research Laboratory of Bhabha Atomic Energy Centre, Mumbai, after successfully graduating from the 37th batch of BARC Training School in Physics Discipline. Subsequently he joined the Reactor Physics Division of the Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam and worked on the reactor physics aspects of the U-233 fueled Kalpakkam Mini Reactor (KAMINI) and core neutronic design of the Prototype Fast Breeder Reactor (PFBR) that is getting constructed at Kalpakkam. He had obtained his doctoral degree in Reactor Physics from the University of Madras. He worked as a Consultant in the Planning and Economic Studies Section (PESS) of the IAEA during Oct-Dec 2006 under the PESS-INPRO joint study for Nuclear Power Development Scenario in India. Dr. Mohapatra is currently heading the Reactor and Radiological Safety Section of the Safety Research Institute of Atomic Energy Regulatory Board of India. His field of research includes; Nuclear Reactor Physics, Nuclear Safety and Radiation Physics.

Lakshmi Hansda
Project Associate, National Institute of Advanced Studies

Miss Lakshmi Hansda is a graduate in Electronics & Telecommunications Engineering in the year 2014 from Indian Institute of Engineering Science and Technology Shibpur, West Bengal. Ms. Hansda has hands on experience in organizations such as BSNL Circle Telecom Center on telecommunication networks, mobile technologies, including GSM and CDMA, and emerging trends in telecom networking. She has also done a Project on PLC (Programmable Logical Controller) in ERTL Kolkata (Electronics Regional Test Laboratory). Ms Lakshmi holds a Master's degree in Reliability Engineering from Indian Institute of Technology, Kharagpur. During her M.Tech program she has worked on a project which was a joint venture with RDSO (Research Design & Standard Organization) under the Ministry of Railways, India. It aimed to analyse the Reliability, Availability & Maintainability of Diesel Locomotives. Recently, she worked as Junior Manager-R&D in one of the largest and only integrated manufacturing unit in India for Auto Air Conditioning systems, Subros Limited, with the objective to achieve business excellence through technical specification to reliability analysis in component and system level of AC machines.

Summary of the first Meeting of the Core Group on Human Reliability Programin Industries of National Importance

The Core Group Meeting on "Human Reliability Program (HRP) in Industries of National Importance" was conducted from October 15 – 17, 2019. It was jointly organized by NIAS and Texas A&M-NSSPI. Out of 16 talks, seven talks were on HRP and Challenges and four on Human Error. Also, there were three talks on Defense and Chemical industry perspectives of HRP, including one on future industrial development. Two talks highlighted the role of academia in improving HRP. The United States Department of Energy (USDOE) has referred to HRP as a safety and security program to ensure personnel occupying critical positions are trustworthy, loyal, and reliable. Similarly, the US Department of Defense and Personal Reliability Program also require that only the most trustworthy individuals have access to critical information or resources. The meeting discussed some challenges of having an HRP and the current state of HRP or HRP like programs in India.

Prof. Sai Baba's talk covered two aspects: the Challenges of HRP and summary of April 2019 HRP meeting. The talk started with Prof. Sai Baba pointing out the facets of HRP, which are decision making, complementing security, and improving employee quality. He emphasized that it was not only important to police employees, management evaluation also play a critical role. The talk went ahead to explain why psychological testing and interviews should be a part of HRP. Ongoing education and testing should also be an inevitable part of HRP. Some challenges to HRP as outlined by Prof. Sai Baba were problems of sabotage and the reliability of humans in the technology age. Furthermore, measuring the transition of human beings from normal to abnormal (behavior potentially threatening to safety) behavior is an enormous challenge to HRP. It is also critical to know if this is a transition or an abrupt event. Currently, screening processes are in place in Indian nuclear facilities before hiring employees. Prof. Sai Baba's talk had the underlying presumption that human response to any technology is constant whereas technology is dynamic. Hence, the talk had a strong emphasis on testing people. It went ahead to propose testing people differently in case they oppose or protest. Some other challenges outlined by Prof. Sai Baba were understanding and accommodating diversity and identifying the odd person.

The second part of the talk presented the summary of the April 2019 HRP meeting organized jointly by NIAS and Texas A&M University. Different collaborators for HRP for industries of national importance were mentioned and their contributions were acknowledged. The meeting held in April 2019 had a strong focus on HRP implementation challenges. Some key takeaways from the meeting were identification of good practices of safety and security concerning HRP across countries, multidisciplinary nature of HRP hence inputs are needed from policymakers, think tanks, academia, and industry and close collaboration with industry to inform future challenges to academia. The talk ended with giving the highlights of the participant's feedback.

Dr. Chirayath provided insight into HRP from the security side of things. According to Dr. Chirayath, making sure people working in the facility are safe and secure is the objective of HRP. However,

it has some added benefits too. These benefits include mitigating insider risks, retention of valued employees, etc. Dr. Chirayath defined an 'insider' to be an individual having access, knowledge, and authority. Based on these attributes an insider can perform some harmful activities, which are deliberate in nature. The talk then proceeded to provide a snapshot of HRP followed in the USA. Defense-in-Depth philosophy is adopted by HRP personnel and practitioners in the USA. They follow a prevent, detect, and respond framework. The detection aspect has four elements. Dr. Chirayath mentioned at the outset of his talk that not every individual has to be HRP certified. Also, there is a process of decertification and recertification through continuous evaluation. The latter two are done every three years via various forms of medical and psychological assessments along with several other checks. It is not as elaborate as the evaluations and tests of certification though. Dr. Chirayath highlighted the supervisor concerns; however, many more exist. A challenge to HRP is how to prevent these concerns from occurring. Secondly, the cost of certification in the USA is high. The talk then shed light on the process of reporting at various levels, different forms available, consent, etc. The importance and definition of ethical behavior in the USA concerning HRP were explained by Dr. Chirayath. The last part of the talk pondered on HRP in India. He mentioned elements of HRP can be different, but some may be common. In this line, Dr. Chirayath presented a five-stage HRP prescription as developed by USNRC and ORNL which was also presented in the April 2019 meeting.

In the second presentation, Dr. Chirayath talked about three HRP related cases, which happened in a defense submarine facility. Out of 5000 employee servicemen 1024 were PRP certified. In the weapons program, they use the term *personal reliability program* (PRP) instead of HRP, but the principles are similar. Not every person has to be PRP certified. Some cases concerning PRP-certified people from 1975 -90 have been shown how there is a decreasing trend in the decertification program. During the period from 1975-1984, around 4.5% (around 51,000 people) per year on average were decertified from the PRP and it became 3% towards the end of 1985. A lot of decertification has been found which reached a peak at some point.

A committee has been set up to find and fix the problem, to find which triggers the causes or how the number of decertified people can be reduced. The current data in the year 2003 is about 3%. The committee contributed to finding which one causes the highest decertification among drug addiction, security, or alcoholism. Three case studies on nuclear fuel cycle facilities were discussed. Each of the three examples occurred at different locations in different countries and reported in the international trafficking database. Two of the cases were done by error, but this clarified that things can be done intentionally too. None of these examples got detected by the facility's nuclear security system. People were removed from various positions, and these people were operators, maintenance crews, and security. None of it led to any issues concerning the plant because they were removed before they could do anything wrong.

A regulatory committee has been created to determine how decertification numbers can be reduced. All of the data shown concerned unreliability removal. Depending on the context, how to incorporate the cultural difference between western countries and India needs to be considered in the program. Industries also must look at societal issues as well, otherwise, the trigger may come from any source.

Dr. Lele presented his ideas on HRP in the light of technology disruption. Disruption here is referred to as the advent of something new. Disruption can thus occur at an idea level also. He described a variety of examples such as Thomas Cook, Nokia, Blackberry; companies which did not adapt or cope with the technology disruption have failed. According to Dr. Lele, HRP is a challenge at a very large-scale level. It starts from society to a country to a factory. Every technology will throw some new challenges to human reliability. The importance of not following rules and acting judiciously was highlighted in the talk. An example of aircraft, was shot down on September 1, 1983 in the erstwhile soviet era was used to illustrate this point. However, a few years later a possible World War III was avoided when an individual took a judicious call instead of following rules when the same situation reoccurred. The talk catered to the following points; if human error is an individual shortcoming, how to predict human behavior and what are different aspects of human reliability assessment (HRA) and not HRP. The challenge of predicting human behavior, was explained again with an example of group behavior exhibited by Al Qaeda members and the lone wolf's attack. The former gets motivated and acts on ideas being fed to them however the latter's intention is difficult to determine. Although in the Norway attack the perpetrator had conducted extensive internet research on chemical, biological, radiological, and nuclear weapons.

The talk then focused on HRA in the defense domain. It began with HRA in the aviation domain which always focused on the pilot. Several technologies are going into various industries of defense such as electronics, weapon development, and sensors. There is a total lacuna of HRA and HRP in these domains as pointed out by Dr. Lele. Some industries for Naval warfare have no HRA data altogether. The talk then concluded areas to contemplate for the development of a comprehensive HRP. Some of them are human reliability in space. If an individual stays in space for 500 days, then traditional existing models of human reliability will cease to apply. India has gone through a hybrid revolution of military technologies such as that of cyber tools and quantum platforms. However, there is no mention of human reliability anywhere. Finally, what is the fate of any HRP in the industry 4.0 era?

Dr. Ray provided a picture of human reliability practices in the chemical industry. Dr. Ray put forward the fact that practices are under the envelope of HRA but not explicitly called HRA. Through the example of Benzene process, he emphasized not having a one-size-fits-all HRP program. People should be treated differently based on where they come from. One way of doing this is a psychometric testing model of group behavior like Meyer's Briggs. Dr. Ray pointed out three key aspects that should be kept in mind when framing HRP for industries. They are:

1. we must recognize the variety of psychological backgrounds of people entering the industry
2. the severity of a disaster is very high
3. detection and mitigation systems in some industries are not the latest.

Dr. Ray suggested to take measurable indicators and run a study that links to those indicators at physiological levels/data. For example, the single largest retail petrochemical product is a baby diaper. We have fatality measurements, accident measurements but no measurement of renal functions. According to Dr. Ray, HRP needs to help us pick up the behavior of people who are working in critical

situations such as maintenance. He cited the example of incident at a cold cream plant in South India. Water and oil were separating at the plant but not at the IICP lab as someone switched the motors. Some key issues of the chemical industry as highlighted by Dr. Ray are:

1) Procedures are complex to understand and the complexity of chemical processes increases in batch processes.
2) Typically, a chemical plant runs with one operator and one person in the control room and not much manual work to do.

Communication and procedures between these two must be properly managed for safety. This is possible in big industries. However, in India, 80% of chemicals come from Micro, Small, and Medium Enterprises (MSMEs). How do we manage there?

The talk then dwelled on the notion whether an average Indian is more neurotic than his Western counterpart? If so, then this calls for identifications of early signs. Hence, the idea of observing is not such a bad idea and it would enable and not threaten. However, this has to be done in a structured manner. Some methods of doing it in a structured fashion are:

1) Integrity pact: In this pact an individual authorizes a third party to have access to everything he or she has, papers, documents, files, bank statements, etc.
2) HAZOP: Considers HRA aspects peripherally and not explicitly. Good to start with.

The talk then concluded with some challenges and questions for HRP. Some of them are: How does one implement HRP of road tanker drivers? Unlike in the west where the level of education in the drivers is in higher, can the use of HRA be turned into opportunities?

Ms. Kanagalakshmi Natarajan's talk emphasized the concept of system thinking in socio-technical systems such as that of nuclear power plants. Her talk provided an interesting example of Monday morning minor injuries of some female employees. On investigation the causes for the same was found to be domestic abuse by alcoholic husbands, which resulted in no food consumption for 48 hours. A solution to this was found by enrolling these women in an ISO management program. In the program, once ladies were comfortable, they opened up about the cause to the concerned official interacting with them. To overcome this problem the supervisors were given a duty to ensure that the women who comes to work take their breakfast at the facility before starting their assignments.

The talk proposed the term 'incident genesis' in place of 'accident analysis'. It provided various frameworks for the same (eg. Henirich, 1931; Rasmussen, 1982, Wagnor et al., 1990, etc.). The next section of the talk pondered on the cause behind human error. Overload, inappropriate activities and responses as causes of human error were put forward in her talk. Each of those causes has several factors nested within. For example, situational factors (unclear instructions, risk level) are nested under overload. Hence, pep talks to make people aware of which situation they will be exposed to, can be useful and is in practice in BHAVINI according to the speaker. Similarly, performing a task without

training is nested under inappropriate activities. This is typically seen in contractual workers. Misjudging the degree of risk is also seen as inappropriate activity. The line manager should enlighten people about the risks in the control room to prevent misjudging.

The talk then moved to provide a very detailed theoretical background of human error. Sydney Dekker's field guide to understanding human error and Reason, were the main sources for the same. Ms. Natarajan then focused on active and latent error and provided various error taxonomies for the same. For example, Swain & Guttman (1983), Rasmussen's taxonomy (1986), and Reason's taxonomy (1980). Ms. Natarajan highlighted the quantification of the error to be very important. The talk also provided some information about cognitive models of NPP such as IDAC operator's cognitive model, Klein's macro cognitive model. Ms. Natarajan concluded with the following points:

1) system's thinking in practice does not always work
2) allocation of jobs and profiling can help to reduce human error
3) Error data archive
4) HRA should be taught to every employee to the extent possible.

Dr. Gopika Vinod's talk dwelled on human reliability from the perspective of person shaping factors (PSF) perspective in the Indian context. A clear demarcation of safety and security was made at the onset. It was also stated at the beginning that the experiments done at Dr. Vinod's facility assumes slips, lapses, and mistakes to be the cause of human error. Following a quick introduction and explanation of the Probabilistic Safety Assessment and its difference from deterministic safety assessment, she went on to describe her risk matrices, like nuclear reactor core damage frequency and large early release frequency.

She considered hardware and human reliability together in her studies. To appropriately quantify human error probability, humans as a component were considered and accounted for possible failure events. Accounting for all possible failure modes is a challenge. Furthermore, getting data on human failure events, representation of less significant human errors, and recovery time are also mentioned as challenges. She described tasks to be interdependent, which makes data extraction very difficult. The research was carried out by conducting the experiments in virtual simulators to generate context-sensitive data. Use of virtual simulator yielded economic benefits as making changes in a full-scope simulator is not easy. The talk then progressed to discuss various human error models. Three generations of human error models exist she observed that only first-generation models are being used. Among first-generation models (such as THERP, HCR, HEART) some models are heavily expert judgement dependent, and some only cater to training and complexity of the task. All attributes in any human error model are equally significant but no model considers probabilistic safety factors (PSFs) from all aspects of nuclear power plant operation. With all these considerations SPAR-H was considered most suitable. The Bayesian network was used to modify human error probability (HEP) values by original SPAR-H to suit the Indian context. Thus, a list of new PSFs was derived and a new PSF was added to the model to suit the Indian context. She indicated that based on their study it was observed that the operators were very reluctant to work in a virtual environment. They are also not comfortable

with advanced tools. She concluded by observing that the current human reliability scenario lacks the system's thinking. For example, there are no human error models that cater to management aspect, shift transfer, safety culture, etc. She recommended striking a balance between procedures and flexible decisions. Also, we should consider whether our current models go beyond design? Can a system bounce back; what is the resilience of our system?

Mr. Seshaiah Mupparaju's talk focused on those human factor issues which come into play while responding to Design Extended Conditions (DEC) such as that of Fukushima in NPP (nuclear power plant). The talk was structured on the idea, personnel in addition to being equipped with technical skills need to be equipped with nontechnical skills (social and psychological) too. Additionally, the importance of effective teamwork and coordination during design extended conditions was emphasized in his talk. Mr. Mupparaju explained PSF and its kinds (physiological and psychological) followed by various factors which influence human behavior in design extended conditions. The factors are cognitive (mindfulness, situation awareness, communication, decision making, adversity quotient, positive psychological capital), emotional (emotional intelligence, and stress management), and behavioral (crisis leadership, followership, and effective teamwork). The talk described the process of decision-making. It explained Benner's model, decision making strategies (intuitive, rule bases, creative, etc.), factors affecting decision making, and steps to effective decision making. The talk concluded by describing three kinds of error probabilities, latent, initiators, and post initiators.

In her talk, Dr. Ipshita Chowdhury highlighted the importance of a systems thinking in an HRP. Dr. Chowdhury started off the talk with the effectiveness of systems approach over the traditional reductionist approach in solving drugged driving problem in Australia. The talk then highlighted the key tenants of the systems approach which are:

1) multiple contributing factors spanning multiple hierarchical system levels,
2) multiple actors and shared responsibility, and
3) up and out approach.

The talk then provided a case example of Rasmussen's risk management framework of a gorge incident. Her talk also dwelled on the role of situational awareness in safety. Some theoretical explanations of the construct were provided. Three schools of thought exist to explain how individuals maintain and develop situational awareness. Distributed Situation Awareness explains how purposeful interactions between various agents leads to safety. Thus, safety can be enhanced if humans are not taken in isolation. This was explained with the example of the crash of AF 447.

The penultimate portion of the talk demonstrated how propositional networks can be used to extract system vulnerabilities. The analysis of AF 447 revealed how it was the designer error (sidestick not visible to the copilot, angle attack not displayed, poor crew resource management, and ECAM malfunction amongst many others) and not the pilot error that led to the fatal crash. The talk finally concluded with some future directions for the HRP program, one of which is creating a knowledge base of human reliability and related areas and the need for the development of systems-based measurement tools.

Dr. Vivek Kant discussed the barriers and challenges of creating a consolidated HRP in India. Three ideas that were presented are:

i) Academic fragmentation,
ii) Lack of development of academic disciplines related to human and engineering, and
iii) Disconnect between academic industry and the government sector and everyday needs and requirements in the sectors.

Government, regulators, company, management, staff, processes, work are all factors involved in any safety-critical system. Each of these entities address their own viewpoints on what things should be like. At each level of work or interaction, humans are being conceptualized differently. There is a need for introducing an interdisciplinary course on human reliability in India. If we want to develop human factors, then we need to understand what is human and how humans are conceptualized in this human factor. Science looks at analysis, engineers look at synthesis. The human factors discipline is a hybrid. Dr Kant opined that in terms of academic conceptualization there is a gap in India in human factors consideration.

The difference between hard and soft sciences needs to be considered. Simply quantifying everything will not give us the solution. At physical and physiological levels, India is very good in ergonomics (ergo=work, nomos=laws) but at the level of cognition where cognitive work or human decision making is required, we do not have a good academic program at all. The synergy between academia, government, and the industry is required at a broader level, not only at level of an individual project.

Most of the solutions are in response to symptoms that is, if there is a symptom then find a solution and the symptoms will go away. However the way technology is developing is that systemic challenges are arising. We must look at a systemic solution rather than a symptomatic solution. Along with ergonomics there is a lack of system engineering in the country. The next steps should include creating a comprehensive basis for engaging human factors at a broader academic level, creating a consumer academic syllabus, and making human factors well connected at the National level.

Prof. Manas Mandal talked about the need for end-user integration of any engineering product, which requires the right kind of assessment between technological system and human system. Most system fails at the end-user Integration. The Socio-technical system at an academic level is essentially required. If we must comprehensively develop HRP then three things must need to be discussed those are:

i) inter-disciplinarity
ii) inter-institutional and
iii) deliverability.

Ninety percent of human theories are based on 10% of the human population. HRP should be such that you must get a selection criteria system by which one can get a fully reliable person, who is free

from embedded errors. HRP issues of psychological relevance can be issues like the inability to deal with stress, hostility towards fellow workers, significant behavioral changes, absenteeism, depression, etc.

Human behavior has three major components, cognitive, emotional, and motor. Human error can be behavioral, environmental, and pathological. The human system can be screened in a systematic way by rejection, selection, and decision systems. Rejection criteria are based on proficiency, performance, attitude test, problem-solving strategies, decision-making strategies. Selection criteria are based on personalized reliability, work attitude, and commitment. Work attitude and the trainability of the person and decision criteria is based on the capacity to hibernate, infuse team spirit, and a high tolerance for ambiguity and to the ability to remain resilient, communication skills with content and intent of speech assessment. The presence of positive traits and the absence of negative traits is equally important in decision-making system.

Error proneness is embedded in the human system. Unless we understand humans, we will not be able to create a program to select people who are reliable enough. Academic programs in India that teaches how to take a decision is sparse. When developing an HRP attentional errors, thinking errors, memory errors, perceptual errors, and decision-making errors need to be taken care of. In industries of national importance, the threats of sabotage and malicious intent need to be checked.

The next level of challenge is the validation of HRP. An HRP program should be there not to judge someone or not to qualify someone or not to reject someone but for the wellness of people, for the safety ensured, and to prevent any potential threat on human or operation or to check whether someone can be given higher responsibility or not.

Dr. Reshmi Kazi talked about human reliability as an integral requirement in all critical infrastructure including nuclear industries and is very important in all sensitive installations. The rapid spread of information technology and an increase in terrorism mandates an increasing necessity of effective HRPs. There is always a possibility of the high vulnerability of sabotage or unauthorized access to the use of sensitive materials, information, and systems of a nuclear facility.

HRP is an evolution plan to ensure that only trustworthy people who are physically, psychologically, and professionally capable are authorized to work in a critical infrastructure facility. The system must be able to test people whether individuals are competent to undertake sensitive responsibilities. HRP puts the challenge where an individual's competency might get disregarded leading to disgruntlement that heightens the risk of insider threat. Efforts at screening for behavior will also be inevitable. The concern is failing to identify someone who has a disqualifying background or behaivor.

The academic institutions have a critical role to play. She observed that most of the sources that are generally referred to while accounting for the relevance of HRP are primarily from the Western domain. The academic community has a significant responsibility to develop a narrative on India's critical requirements premised upon a framework that pertains to our potential threats and vulnerabilities. For

this purpose, academic institutions must be more forthcoming with organizing various workshops, seminars, and conferences to generate awareness and interest in this critical domain.

The HRP must not generate a culture of fear. We should enable personnel to become their advocates and allow them to freely engage in conversation with the HRP officials without being judged on their personal choices as opposed to their reliability. A fruitful exercise can be where various institutions engage in exchange programs to give exposure to students that will enhance their interest in this area of study. The art of war teaches us to rely not on the likelihood of the enemies not coming but, on our readiness, to receive them, not on the chance of he or she is not coming but rather on the fact that we have made our position unassailable.

Dr. Xavier Raj in his talk discussed about living in a dynamic environment. We are moving towards life in industry 4.0, which is supposed to be the converging of physical, social, and cyber areas. We have a lot of diversity and there are differences in India in terms of social, cultural, governmental, ideological, economical, and political perspectives of HRP. All these factors influence humans. It also brings a certain kind of learning from other industries and some of the technologies from other industries can be adopted. It is possible to do because enormous data is there, which is useful for us to visualize, contextualize, and be customized for the need. We can move from predicting anticipatory maintenance to preventive maintenance, which is much more complex even though it looks simple.

He referred to a survey done which includes 30,000 personnel working in the processing, managing, transporting department in nuclear industries. The survey showed that there is a huge difference between the manager, and the operators in the way they perceive safety and this gap is consistent. An organization can proceed to take action to overcome these types of problems. To create the culture of safety and security, three essential elements need to be developed namely:

i) beliefs and attitudes,
ii) management systems, and
iii) behaviors.

A system of management must be put in place to import expectation requirements and standards for the conduct of work and training among workers and managers. The strength of nuclear safety and security cultures in an organization is observable in the behavior patterns of its personnel, which can be improved by continuous learning, self-assessment, and application of the best practices and lessons learned.

What is being done to avoid unintended events is to: setting up systems, giving proper training to people on critical thinking and providing redundancy. There is a need to look into measures which can aid in preventing the intentional error. Neither culture of safety nor the culture of security is going to address this. We should clarify whether we want to go for standardization like the Chinese or Koreans or want to bring flexibility by balancing things properly. Cultural security demands confidentiality whereas cultural safety often requires sharing. This must be clearly understood. We need to bring a

diverse set of people which will give certain perspectives also we need to qualify and quantify. As India is planning for an increase in the number of nuclear sectors, the core group on HRP can continue working together, which will be a very good contribution to society.

Mr. D. K. Shukla dwelled in his talk on the rise of accidents due to human error which has risen to 80%, while those due to machine have come down from 80 to 20%. It is not because humans have become unreliable, but it is because machines have became more reliable, so human causes have become more prominent. If we want further improvement in safety performance, it cannot come unless we address the human causes. Even today when any incident takes place, we try to take care through the technical measures, but we do not look at the human cognitive part. A typical Root Cause Analysis (RCA) attributes events directly to people's carelessness and poor safety attitude. But in RCA we do not address latent failures associated with human and organizational factors. RCA must identify underlying HOFs (Human and Organization Factors) keeping in mind that the important principle of any error management is that 'errors are consequences not the cause'. Organization affects the way people behave or act. We measure reliability by unreliability data. We take the data where human has failed, but there are many accidental events which never occurred because of human actions. HRP should not be purely based on the negative side of the human. We should take the positive side also. Humans are unreliable sources of reliability.

In the techno organization system, there are chances of active and latent errors. The active errors are committed by the people who work at a human system interface like pilots in the aviation industry. These are errors of commission and omission and these are unique to specific events and have immediate consequences. The latent failure is due to the decisions made by the organizations, corporate level, designer, manufacturer, constructors' managers, etc. and outside the organization like the regulatory body. The latent failures may not come out immediately. There is a huge gap between committing an error and the consequences of it coming out. The latent error may lie dormant for a long time. It can accumulate, and combine with other latent failures and finally can be triggered by an active failure. The same latent error can cause several different accidents. That is why latent errors are very important. Just taking care of active failures alone does not serve the purpose of safety. Skill-based error is mainly caused by distraction and interruption, where we are more prone to commit the error. A lapse occurs because of an error of commission. In skill-based error, the action is unintended, but the intention may be correct. In rule-based error action is intended, it is primarily error of judgement. The knowledge-based mistake comes to unanticipated situations where rules and procedures are not available. For that scenario, the experience can help in decision making. For accident causation, Reason's pathogen model and Swiss cheese model can be used. In organisational accidents which happen to complex systems like nuclear power plants or highly hazardous chemical factories having the defense in depth (DiD) where we have multiple layers of defense. While DiD greatly reduces the likelihood of severe accidents, it also makes the hazard more opaque to people who are managing them.

To reduce unintended actions, carefully designed and well-implemented management systems with strong policies and objectives should be in place to protect the organizations. Strong policy and objectives need to be there. Establishing and maintaining a healthy safety culture, proper vision,

mission, resources, and motivation should be there in an organization. Roles and responsibilities at each level should be clearly defined. Communication, regulation, training, licensing, and delicensing that is what is being done and why is it being done everything needs to be taken care of. Emphasis should be on what is reported or what went wrong rather than who has reported or who went wrong. Blame free analysis will result in better output. Rules, practices, and procedures should be practical and relevant otherwise they are likely to be bypassed. Reporting, monitoring, and feedback at all levels will help in analysing the situations and mitigate errors.

Dr. K.L. Ramakumar talked about the continually evolving discipline of human reliability assessment, which involves the use of qualitative and quantitative methods to assess the human contribution to risk. To improve human reliability the causes of human errors should be identified, and the probability of human errors should be quantified. The nucleus of human reliability is to find credible ways of helping designers, management, operators, and authorities to increase the safety and profitability of technological systems after having identified the risks and their probability. The next step can then be taken to decide what, how, and when changes should be made.

It is essential to recognize the special needs and requirements of operators. The knowledge and understanding of the analyst and the operators are not the same. Sociology and engineering appear to be completely incompatible but there are some important reasons why engineers should want to acquire and appreciate sociology related knowledge in their profession. It will help the understanding of the complex and often confusing nature of humans and as an individual and as a collective, will broaden one's vision and skills also.

An ideal HRP should ensure that individuals who occupy positions with access to critical operations and assets meet the highest standards so that they adhere to safety and security rules and regulations, ensure confidence in individuals based on their character and their physical and mental stability. Three main research directions are: i) the method for prediction of probability of human error ii) decision trees, and iii) fuzzy expert systems. The basic steps like batch recruitment of qualified people with necessary educational background through a written examination followed by personal interview, periodic assessment of the trainees, motivating the staffs to ensure quality measurements in the analytical laboratory in a nuclear research institute was elaborated by the Dr. Ramakumar.

The HRP concept implies that one can do something to avoid human errors and it is not a case of firing error-prone individuals. Errors often occur due to the context in which the humans are placed. HRP as a discipline needs to have an academic orientation. Human factors and ergonomics expertise can benefit the development of an academic system. There is an urgent need to constantly evaluate the benefits of new technology in the classroom as well as the environmental design aspects of the educational environment while considering learners of different age groups, ethnicities, and sexes. While the factors contributing to human factors differ very largely, there could be some common thread that could be taken into consideration in assessing human reliability which could also become quite handy in extending the assessment of that individual in future assignments.

Mr. G.R. Srinivasan's presentation covered two parts. The first on human reliability in the nuclear energy section and the second on areas of human reliability for further deliberations. On several points, he linked the items between these two. Nuclear industry adopts a two-fold approach to human reliability. Good practices in design and operation should reduce dependence on human reliability to a minimum. Notwithstanding this, monumental effort is required to strengthen human reliability. This is done as a lack of human reliability affects not just a particular nuclear power plant but its growth globally. A nuclear accident anywhere is an accident everywhere, not geographically but in terms of public acceptance wise. Ingredients of safety and security cultures are common to human reliability. Nuclear organizations invest heavily in human reliability, in addition to strengthening safety and security, it also improves production and profitably. Methods and practices in the design and operation of nuclear power plants, which keep human reliability at a high level, were discussed.

The following items were suggested for future deliberations. For conducting and strengthening human reliability audits, the following steps are required:

A. Details of the following steps to be worked out:
    1 List ingredients/characteristics for strong human reliability
    2 Develop performance indicators.
    3 Develop detailed format/procedure for human reliability audit, using these performance indicators.
    4 Determine gaps between 1 and 3 and detail out steps to strengthen these gaps.
    5 Make a format for human reliability audit from 1 to 5
B. Interconnection between HRP and Human relations to be worked out.
C. What are management and individual responsibilities for achieving good human reliability?

A meeting to share cross-industry good practices in HR will be useful. Critical industries and tasks with respect to HR needs to be listed.

Dr. Kallol Roy's talk envisioned how a nuclear power plant would look in the industry 4.0 era regarding safety. Dr. Roy explained how and where a program HRP fits in the nuclear industry pyramid. This was then followed by a discussion on various stages of the industrial revolution and how industry 4.0 looks for the nuclear industry. In particular, the focus was on safety aspects in cyber-physical domains. A large part of his talk catered to the training and licensing of nuclear power plant personnel in the industry 4.0 era. Here, the role of micro-education was highlighted. For example, app-based drivers are trained for 15 days to use technology while driving. Similar specialized and customized education should be a thrust area for NPP personnel. In the era of industry 4.0, intelligent systems will be able to layout the built-up of an event to an operator according to Dr. Roy. Currently, this is not possible and is not being done. This will also call for an important aspect of the degree of automation in an NPP. Similarly, intelligent alarm systems (will prompt the operator to follow standard operating procedures), online data processing, and improved ergonomics and anthropometrics will be brought about by industry 4.0 in an NPP as opined by Dr. Roy. Despite this, there will be room for human error, if the role of designers and design perception are not taken into consideration. The last part of the talk dwelled on training in virtual reality (VR). To do so the industry needs high-quality VR models. Also,

while constructing and using VR it has to be kept in mind the user of those will be industry and finance driven. Thus, it should not be a passion-driven project only. Moreover, Dr. Roy pointed out that, there is a need for strong industry and academia collaboration. Operators and think tanks should collaborate to try to understand how individuals behave in an NPP and this can be the way forward for industry 4.0 ready digital NPP. This kind of overhauling particularly with a strong focus on understanding human behavior needs industrial psychologists, cognitive scientists, and human behavior enthusiasts. The talk concluded with the important role of training at all levels. To do so academic institutions have a very critical role to play.

Panel Discussion Summary

One of the objectives of presentations and deliberations on the first two days of the core-group meeting was to prepare a set of questions for the panel discussion planned for the third day of the meeting. The panel discussion was chaired and led by Mr. D.K. Shukla, with Dr. K.L. Ramakumar, Dr. Kallol Roy, Mr. R. Satyanarayana, Dr. D.K. Srivastava and Mr. G. Srinivasan as other panel members. The panel discussion was coordinated by Dr. Sunil S. Chirayath and Prof. M. Sai Baba. A set of questions were prepared for the panel discussion and answers/comments by the panel on these questions are given below.

1. Deliberations on the first two days of this core-group meeting brought out the fact that HRP is being implemented in some fashion in aerospace, airlines, defence, biotechnology, Nuclear Power Corporation, National Thermal Power Corporation, and chemical industries in India. The data on human performance will be beneficial if it is systematically collected and discussed domestically among experts. Given the fact that each critical industry has its own vertical structure the way it operates, is there scope for horizontal (inter-institutional) sharing of lessons learned in human performance? This can also remove the focus on nuclear industry instead focus on the critical industries of national importance. Is human performance data in critical industries of national importance being (systematically) collected?

   Panel response: Defense establishments collect the data systematically. Nuclear Power Corporation of India Limited (NPCIL) collects human error data including occupational data and this data is shared between its units. There is a need to create a database on human performance in critical industries of national importance. Action is needed at the central government ministry level for a database creation of human performance in critical industries of national importance and will be followed up by the end of the core-group study. Panel recommends the development of a culture to document steps taken by personnel that avoided failures or near misses at the workplace. The panel also recommends that HRP should have a provision not only in identifying active errors but also latent errors.

2. Has cultural/physical diversity been an issue in the critical industries of national importance during training and after sufficient training at the workplace?

   Panel response: There have been issues but most of them were identified and rectified. Panel recommends the importance of sharing those good practices being implemented which reflects

the cultural and physical diversity. The important role of being compassionate to colleagues should be brought out in training, taking into consideration the circumstances faced by individuals outside the workplace. An implemented best practice at one of the DAE units, BHAVINI was discussed by the panel regarding this aspect.

3. Does HRP has the potential to be counterproductive being very contextual in its application? How to draw a line for the HRP to be beneficial?

   Panel response: HRP principles should be to aid the operators and not to punish them so that the maximum benefit can be drawn from the program. HRP should create opportunities for managing the unforeseeable circumstances in the workplace even if the foreseeable can be managed by machines.

4. Is there a need for academic curriculum development in human factors so that training becomes easy in the critical industries and experts in this HRP area are produced?

   Panel response: Yes. Academic and basic research institutions should work together for the curriculum development but should be funded by the industry, which will allow an industry informed academic curriculum development and implementation. The curriculum shall strive to initiate studies in humans as a system so that studies on human performances can inform engineering system design. The panel suggested that IIT-Kharagpur and IIT-Bombay can take initiative towards this curriculum development on human factors to enhance the HRP in India.

   As a side note: Human factors in human reliability analysis is being studied at the DAE-BARC. Intentional disruptive human behaviours can be included to modify the human performance shaping factors to extend the human reliability analysis. NIAS researchers can initiate this research aspect of disruptive human behaviours into human reliability analysis.

5. Are there ways to automatically capture an individual's disruptive behaviour as soon as possible at the workplace?

   Panel response: One of the panel members discussed the ongoing studies on psychometrics and behaviour-metrics and its potential implementation to avoid the need for reporting an individual's disruptive behaviour by colleagues. At the same time, the overall sentiment of the panel was not to dehumanize the system operation. It is important to note in this context that in the past decade the HRP decertification is continuing at around 4% in the US. Also, as per the IAEA's International Trafficking Data Base insider behaviour or actions are reasons for most of the events.

6. How much importance is given for continuous training and evaluation of individuals in critical industries of national importance in addition to the screening done at the time of recruitment?

   Panel response: Continuous training and evaluation of individuals are on a need basis and the frequency is dependent on the industry. In the Indian nuclear industry, such evaluations and training

are done on a 3-year basis for re-licensing the operators. The Panel recognized the necessity to move from Human Reliability to Human Validity as the next step.

7. How do people interact with other people while interacting with technology, for example, while using a cell phone?

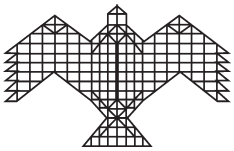
   Panel response: Yes, distraction in the workplace can create havoc and could also lead to the disruptive behaviour for individuals going unnoticed. Alertness at the workplace will contribute positively to the HRP.

8. What is the recommendation of adopting HRP elements in India?

   Panel response: Regional, socio-economic conditions in India shall be given prime importance. Given that many jobs are outsourced to contract workers, it is important to make sure that only the job aspects are outsourced but not the safety and security responsibilities of the operating institution. HRP shall be for critical operators as well for other technicians.


D K Srivastava
Dinesh Kumar Shukla
Ramakumar K.I.
M Sai Baba
Sunil Chirayath
Gopika Vinod


D K Srivastava
Sunil Chirayath
M Sai Baba



National Institute of Advanced Studies
Bengaluru, India

TEXAS A&M UNIVERSITY

Second Meeting of the Core Group
on

Human Reliability Program in Industries of National Importance

October 14-16, 2020

National Institute of Advanced Studies (NIAS), Bengaluru

Jointly Organized by NIAS and Texas A&M University, USA

TEES
TEXAS A&M ENGINEERING EXPERIMENT STATION

NSSPI
CENTER FOR NUCLEAR SECURITY SCIENCE & POLICY INITIATIVES

Introduction

Human Reliability is widely used in fields requiring high standard of safety, such as aviation, petroleum and chemical process and nuclear industries. There is always an inherent risk of human behaviour or actions or inactions, introducing errors into the operation of a system or process. A Human Reliability Program (HRP) could ensure that individuals who occupy positions with access to critical assets/operations/sites meet the highest standards so that they adhere to safety and security rules and regulations (reliability), ensure confidence in individuals based on their character (trustworthiness) and their physical and mental stability. As part of the collaborative research NIAS-Texas A&M University has organised two discussion meetings at NIAS. At the end of the first discussion meeting with larger participation, it was decided to continue the discussions by forming a core group to elaborate further and the first meeting of the core group was held in October 2019. The second meeting of the core group was convened during October 14-16, 2020 using online (Microsoft Team) platform. The focus of the discussions was at understanding the HRP issues across the industries of national importance. The meeting aimed at building on the discussions held in the two previous meetings. Each of the identified topics were discussed in detail to come out with deeper understanding and analysis and identify the domains where further work to be done.

Taking into consideration the situation prevailing in the country and restrictions of travel due to the COVID-19, the meeting was held on a virtual platform (Microsoft Teams) and will be conducted from 16.00 to 18.15 Indian Standard time during October 14-16, 2020. On each day, there would be discussions on three topics each for a duration of 45 minutes. The topics of discussion are listed below.

Day-1

- Summary of the discussions held in the previous two meetings
- Discussion of the Human Reliability Program of Various Countries
- Rules of conduct for Employees working in the central governmental organisations
- Training/Retraining Programs

Day-2

- Role of Background check-up and continuous monitoring
- Annual Medical examination and Health Monitoring
- Personnel Access Control including contractor work force

Day-3

- Aspects influencing the safety and security culture
- Identify the components for implementing in the industries of national importance.
- Summary and Conclusion

We thank you for your active participation in the meetings held earlier and appreciate the support and encouragement. It is our privilege to extend invitation to participate in meeting.

Second Meeting of the Core Group on Human Reliability Program in Industries of National Importance

AGENDA

October 14-16, 2020

Time	Topic	Speaker
16.00-18.15	**October 14 (Wednesday), 2020**	
16.00	Welcome	M. Sai Baba Sunil S. Chirayath
16.05	Participant Introductions & Familiarization	All
16.15	Summary of the Discussions held in the two previous meetings	M. Sai Baba Sunil S. Chirayath
16.35	Opening Remarks	Dinesh Kumar Shukla KL Ramakumar N Ramamoorthy R Satyanarayana
16.55	Discussion of the Human Reliability Program of Various Countries	Sunil S. Chirayath M. Sai Baba
17.15	Rules of Conduct for Employees working in the Central Governmental Organizations	Vagisha Nidhi Amit K Shah
17.30	Training/Retraining Programs	M.V. Seshaiah R. Satyanarayana
18.00	Discussion	All

Time	Topic	Speaker
16.00-18.15	**October 15 (Thursday), 2020**	
16.00	Role of Background check-up and continuous monitoring	Amit K Shah Vagisha Nidhi
16.30	Aspects influencing the safety and security culture	Manas K Mandal
17.15	Personnel Access Control including contractor work force	N Kanagalakshmi Kallol Roy
17.45	Annual Medical examination and Health Monitoring	Amit K Shah Vagisha Nidhi
18.00	Discussion	All

Time	Topic	Speaker
15.00-17.15	**October 16 (Friday, 2020)**	
15.00-15.30	Aspects influencing the safety and security culture in Industry	Dr. Xavier Raj
15.30-16.00	Identify the components for implementing in the industries of national importance	M Sai Baba Amit K Shah
16.00-16.15	Summary	M. Sai Baba Sunil S. Chirayath
16.15-17.15	Discussion	All

Second Meeting of the Core Group on Human Reliability Program in Industries of National Importance

October 14-16, 2020.

Participants

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Second Meeting of the Core Group on Human Reliability Program in Industries of National Importance

October 14-16, 2020.

Brief Biodata of the Participants:

D.K. Shukla

Executive Director of Atomic Energy Regulatory Board (AERB) and the Chairman of Safety Review Committee for Operating Plants (SARCOP), Atomic Energy Regulatory Board, Mumbai, India

Mr. Dinesh Kumar Shukla is a graduate mechanical engineer, with over 37 years of experience in operation and regulation of nuclear and radiation facilities. At present he is serving in Atomic Energy Regulatory Board (AERB) as Distinguished Scientist, Executive Director & Chairman of Safety Review Committee for Operating Plants (SARCOP) and an ex-officio Member of the Board.

Before joining AERB, Mr. Shukla had served BARC for 33 years in various capacities, last being as Head, Reactor Operations Division (ROD). He has been associated with several committees of AERB and BARC Safety Council (BSC) for the design and operational safety review of PHWRs, LWRs, reprocessing plants and radioactive waste management facilities. He was a member of the Management Committee for Board of Radiation & Isotope Technology (BRIT) and also of the Radioisotopes, Radiation Technology and Application Committee (RTAC) of the Board of Research in Nuclear Sciences (BRNS).

Mr. Shukla has provided consultancy to IAEA on matters related to safety of research and power reactors, document preparation and for preparation of program for various IAEA international conferences. He has been associated with review meetings of Convention on Nuclear Safety as part of Indian delegation. He represents India in meetings of OECD-NEA committees (CNRA&CSNI), MDEP Senior Technical Committee, VVER forum and in bilateral meetings with regulatory bodies of other countries.

K.L. Ramakumar

Former Head, Nuclear Controls & Planning Wing, Department of Atomic Energy and former Director, Bhabha Atomic Research Centre, Mumbai

Dr. K.L. Ramakumar has superannuated from the Department of Atomic Energy (DAE), Government of India in 2016 after serving the Department for more than 40 years in different capacities. Before superannuation he was Head, Nuclear Controls & Planning Wing (NCPW) in DAE and also Director, Radiochemistry & Isotope Group in Bhabha Atomic Research Centre, Mumbai. His expertise in the field of nuclear technology encompasses all the stages of nuclear fuel cycle, nuclear safeguards, nuclear safety and nuclear security. As Head, NCPW Dr. Ramakumar is responsible for activities and programmes of International collaborations and Safeguards Division (ICSD), Safety and Security Studies Division (SSSD), Institutional Collaborations and Programmes Division (ICPD), External Relations Division (ERD) and Nuclear Law Division (NLD). In 2007, he organised a three-week course on Nuclear Law under the auspices of Homi Bhabha National Institute.

In addition to his scientific and technical publications, Dr. Ramakumar also delivered talks on policy related topics in: Nuclear safeguards and India's safeguards agreement. Nuclear safety and nuclear security, Nuclear energy the inevitable option R&D in India: a paradoxical situation, Nuclear liability. Other presentations of Dr. Ramakumar include subjects on nuclear safeguards as a powerful tool for ensuring nuclear safety and security, nuclear forensics, nuclear security: National requirements in the context of global governance. He was member of The Standing Advisory Group on Safeguards Implementation (SAGSI), IAEA from 2011-2016 and from 2016 is serving as member of Advisory Group on Nuclear Security (ADSEC), IAEA. He had also participated in two International conferences organised by IDSA in collaboration with Indian Pugwash Society in 2014 and another with PRIO in 2015 and delivered talks. He participated in the High-Level Fissile Material Cut-Off Treaty Experts Preparatory Group meeting held in Geneva during May-June 2018, and in the meeting of Group of Government Experts to discuss various of aspects of Nuclear Disarmament Verification, again in Geneva.

K. Roy

Chairman & Managing Director,Bharatiya Nabhikiya Vidyut Nigam (BHAVINI), Kalpakkam

Dr. Kallol Roy, is from the 28th batch of BARC training school and has received his B.Tech (Electrical) from NIT-Calicut, M.Tech (Electronics Design) from CEDT, IISC-Bangalore and a PhD (Fault Diagnostics) from Systems & Control Dept. IIT-Bombay. He was also a Post-Doc Fellow at the University of Alberta (Canada). Prior to his assumption of the present position as CMD, BHAVINI, he was in charge of total maintenance management, ageing management & refurbishing of all the research-reactors at BARC and also commissioning of new research & test facilities. He had also served in many AERB & BARC safety committees, BRNS committees and was also a Professor of HBNI. His specializations are in Total Plant Maintenance Management, System Fault

Diagnostics, Uncertainty Estimation & Modeling in Instrumentation & Measurement Systems and EMI/EMC Modeling in Computational Electromagnetics framework. Presently, apart from his regular assignments, as CMD BHAVINI, Dr. Roy continues to pursue studies on application of Bayesian Estimation techniques for Project Scheduling & Technology Forecasting and Data Analytics for Plant Performance Optimization.

R. Satyanarayana
Site Director, Kaiga, Nuclear Power Corporation of India Limited

Mr. R. Satyanarayana is a graduate in Electronics & Communications Engineering in the year 1983 from Andhra University, Andhra Pradesh. After completion of training at Baba Atomic Research Centre (BARC) in 1985, he joined Nuclear Power Board and later in 1987 Nuclear Power Corporation of India Limited (NPCIL). He has 34 years of experience in NPCIL, a larger organization under DAE in the field of construction, commissioning, maintenance, production and management in different Indian nuclear power plants. He has abundant exposure and experience at a senior level management position in the organization. He is an expert in reactor control systems; Microprocessor based computer systems, Computerized Data acquisition systems and successfully commissioned these systems in Narora Atomic Power Station (Uttar Pradesh) and Kaiga Generating Station-1&2. He has vast experience in the fields of maintenance, engineering services & plant management. During his tenure as Maintenance Superintendent at KGS, the Kaiga units had created new records of continuous operation. Based on his commendable performance, he was deputed to the 'World Association of Nuclear Operators (WANO), Tokyo, Japan. In acknowledgement with his efforts and commitment, he was elevated to the position of Station Director, Madras Atomic Power Station (MAPS) in January 2016. During his tenure, MAPS-2 recorded continuous operation of 512 days in FY 2018-19, first ever feat achieved in the history of MAPS. Mr. Satyanarayana is an Outstanding Scientist and presently functioning as Site Director, Kaiga Site since December 2018. Since then, he is leading the team in working towards obtaining early clearance from various authorities to quick start construction of Kaiga-5&6. He played an instrumental role in Corporate Social Responsibility (CSR) programs and public outreach activities in the areas of education, health and infrastructure development in the surroundings, involving the external stakeholders and the neighbourhood communities as part of the corporate endeavours. Various CSR programs helped in improving the facilities and standard of living of the public in the surrounding neighbourhood. He is a leader with vision and an inspiring mentor for the younger generation scientists who join the Department of Atomic Energy. In short, he is an asset to the Department of Atomic Energy and Nuclear Power Corporation of India Limited.

M.K. Mandal
Distinguished Visiting Professor, Department of Humanities and Social Sciences, Indian Institute of Technology, Kharagpur

Dr. Manas K Mandal is currently serving as Distinguished Visiting Professor at Indian Institute of Technology - Kharagpur. He was formerly a Distinguished Scientist and Director-General - Life sciences in DRDO [2013-2016]. Prior to this, he was Chief Controller R&D (Life Sciences), DRDO. He was also the Director, Defence Institute of Psychological Research for about nine years. Mandal and his team were given away 'Agni Award for Excellence in self-reliance' for the contribution towards the development of 'Computerized Pilot Selection System' for Air Force. For his overall contribution to psychological sciences, he was elected as the Fellow of National Association of Psychology in India in 2012; and for his contribution to Military Psychology, he was given away the 'Technology Leadership Award' by the Defence Minister of India and the 'Scientist of the Year' award by the Prime Minister of India in 2006 (DRDO). Dr. Mandal specializes in the areas of Neuropsychology and Cognitive Sciences. He has to his credit 12 books, over 100 research papers in international and Indian journals of high repute. These researches are cited in more than 300 international journals and books with over 2000 citations.

A. Xavier Raj
Chief Executive, Loyola Inclusive Innovation Impact Centre (L3iC) Adjunct Faculty, NIAS

Dr. A. Xavier Raj, an experienced Anthropologist, Development Sector Specialist and Human Centred Design Proponent, is Chief Executive at Loyola Inclusive Innovation Impact Centre (L3iC), Chennai. He is also an Adjunct Professor (Honorary Position) in National Institute of Advanced Studies (NIAS), IISc. Campus (Bengaluru). Earlier he served as Professor of Entrepreneurship Management and Chairperson of C.K. Prahalad Centre (LIBA). Xavier has 17 years of corporate experience as business head in global market research and consulting firms: with Blackstone MarketFacts (US firm), Synovate (a British conglomerate), and Ipsos (French company). During this tenure at MNCs established two profit generating specialist divisions. Xavier's core expertise includes Strategic Consulting (multi country), Human Centred Design, UX, Humanitarian Assistance, Design Thinking and Inclusive Innovation. As an Entrepreneur founded TSP Consultancy Services Pvt. Ltd., Serendip Boutique, TechLoyola Organics, YX Infra and GTEC, Canada. Currently mentoring 10+ startups at L3iC. Taught in University of Madras – Social, Cultural, Applied, Ecological and Developmental Anthropology / Sociology, Culture and Management and Business Sustainability.

R. Kazi
Associate Professor, Nelson Mandela Centre for Peace and Conflict Resolution, Jamia Milia Islamia, New Delhi

Dr. Reshmi Kazi is Associate Professor in the Jamia Milia Islamia (Central University). She specializes in nuclear security, nuclear non-proliferation, and nuclear disarmament. Her doctoral thesis is on "Evolution of India's Nuclear Doctrine: A Study of Political, Economic and Technological Dimensions" from Jawaharlal Nehru University, New Delhi. She was Associate Fellow in the Institute for Defence Studies and Analyses, New Delhi (2007–2017). She has written extensively on nuclear security issues and made several presentations including a paper on Nuclear Terrorism and UN Resolution 1540: A South Asian Perspective at the United Nations Headquarters, New York. Her latest publication includes co-edited volume India and Global Nuclear Governance published by Routledge in 2019, Post Nuclear Security Summit Process: Continuing Challenges and Emerging Prospects_(2017) and Nuclear Terrorism: The New Terror of the 21st Century (2013). She is an alumnus of National Defense University's Near East South Asia Center for Strategic Study, Washington DC and a Visiting Fellow (Summer 2016) for the South Asia programme in the Stimson Center, Washington DC. Her aim is to research and publish on critical areas pertaining to nuclear issues that can contribute to future policy making.

S. Seth
Member, NCPW, DAE, Mumbai

Mr. Saras Seth is a mechanical engineer graduated from the 35th batch of BARC Training School. After completion of one-year orientation training course, he joined Heavy Water Plant, Kota (HWPK) and has worked in various capacities in the plant and in almost all the departments right from Plant Operation, Technical Services, In Service Inspection (ISI) to Maintenance. He has been instrumental in implementation of projects like Effluent Cooling Tower, Layered Bed Exchangers, Heavy Water Clean-up Facility etc.

He is ISNT UT Level-II qualified person and has completed his MBA in Human Resource management from IGNOU. He has contributed immensely in establishing and streamlining the ISI program at HWPK. He facilitated introduction of many latest non-destructive testing methods in the plant during Extended Major Turn Around post completion of plant design life of 25 years. As a result, Residual Life assessment of HWP Kota which handles large amounts of highly toxic and corrosive Hydrogen Sulphide gas was carried out successfully and boosted the confidence that all major life limiting equipment were intact.

He started his assignment at Nuclear Controls and Planning Wing (NCPW), DAE Mumbai in November 2017. At NCPW, he is working in International Cooperation and safeguards Division (ICSD) and coordinating the activities of GCNEP, especially deputation of Indian Experts to BAEC (Bangladesh Atomic Energy Commission), Bangladesh for consultancy on their maiden Nuclear Power Plant

coming up at Rooppur. Mr. Seth was awarded DAE Group Achievement Award -2013 for "Indigenous Development of Crank Rotor Shaft of Nitrogen Gas Reciprocating Compressor".

Seshaiah Mupparaju
Training Superintendent, Scientific Officer (H) National Power Corporation of India Limited (NPCIL), Kaiga

Mr. M. Seshaiah is a graduate in Electronics & Communications Engineering with distinction in the year 1990 from Andhra University, Andhra Pradesh. He joined Nuclear Power Corporation of India Limited (NPCIL)in the year 1990. He has 28 years of experience in NPCIL. He is an expert in state of art reactor control systems like regulation and protection systems, Computer based process control systems, Computerized operator information systems, advanced access control systems and nuclear security systems and successfully commissioned these systems in Narora Atomic Power Station (Uttar Pradesh) and Kaiga Generating Station-1&2 (Karnataka). During his tenure as Head, Control & Instrumentation at KGS-1&2, the Kaiga units had created new records of continuous operation. As a chairman of Public Awareness Campaign (PAC), he played an instrumental role in educating and improving awareness about the Nuclear Technologies. By recognition of his excellent contributions and self-motivation, he had been awarded NPCIL Special contribution award and Group Achievement Award by the Chairman & Managing Director under NPCIL High Performers Scheme.

N. Kanagalakshmi
Engineer-In-Charge, Fire & Industrial Safety, Scientific Officer (F)
Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), Kalpakkam

Ms. N. Kanagalakshmi is having 15 years of work experience and presently working as an Engineer-In-charge, Fire & Industrial Safety Section and designated as a Fire Protection Engineer. She is basically a Mechanical Engineer and completed her Master's Degree in Industrial Safety. She is taking care of the fire and industrial aspects at Prototype Fast Breeder Reactor (PFBR). She is capable of carrying out various analysis and legal clearances such as Legal statutes related to HSE, Safety Audits, Risk Assessments, HAZOP, FMEA, PHA, JHA, FTA, ETA, TA, Root cause Analysis Techniques, Accident Investigation techniques, Fire Probabilistic safety Analysis, Lead Auditor-OHSAS 18001, ISO 14001, Ergonomic assessments, Workplace analysis, Safety Trainings, Fire Management, Fire Hazard Analysis, Fire Audit, Vulnerability Analysis & Disaster Management Plan, Environment Management, Environment Clearance & approvals, conducting Emergency evacuation drills at offices, high rise buildings, schools and hospitals. She has presented several papers in national and international conferences and contributed for the monograph publications jointly with AERB.

V.M.M. Raj
Scientific Officer (E), Turbine Plant, BHAVINI

Mr. V. Magesh Mari Raj is basically a mechanical engineer having more than 15 of years of experience in procurement, erection and commissioning of power plant equipment. He did his B.E(Mech) from Madurai Kamaraj University in the year 1999 and did his Master of Engineering (Thermal Plant Engineering) from Bharathidasan University in the year 2002. Presently he is working as scientific officer/E at Bharatiya Nabhikiya Vidyut Nigam Limited, Kalpakkam and completely involved in the steam water system package of PFBR Project. He is also working for Probabilistic Safety Assessment of PFBR. Prior to join BHAVINI, he was working as engineer at Tata Projects Limited, Hyderabad. He has been recipient of Senior Research Fellowship from Safety Research Institute, Atomic Energy Regulatory Board (Year 2004 – 2005) and Senior Project Fellowship from Central Electro Chemical Research Institute, CSIR (Year 2002). He is certified welding technologist from IIW, Kolkata. He is member of professional bodies such as Indian society of non-destructive testing and Society for Reliability and Safety, India. Apart from hardcore engineering, his pursuit of interest is ancient wisdom, Tamil literature especially Thirukural, Mudras and Yoga.

S.S. Chirayath
Associate Professor of Nuclear Engineering
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Prof. Chirayath is the Director of the Center for Nuclear Security Science & Policy Initiatives (NSSPI) at Texas A&M University with a joint appointment of Associate Professor in the Department of Nuclear Engineering. He holds a specially appointed Associate Professorship in the Tokyo Institute of Technology where he spends 3 months per year and also is an honorary professor in the Amity Institute Nuclear Science and Technology at Amity University. He is an adjunct Professor at the National Institute of Advanced Studies, Bengaluru, India. His B.Sc. (University of Calicut), M.Sc. (University of Calicut), and Ph.D. (University of Madras) degrees are in Physics. He also was a Bhabha Atomic Research Center Stipendiary Trainee for one year at Tarapur in India. Previous positions include: Scientific Assistant, Indian Atomic Energy Regulatory Board, Mumbai (1991 - 1998); Scientific Officer, Indian Atomic Energy Regulatory Board, Kalpakkam (1998 - 2007); Postdoctoral Research Associate, Texas A&M University (2007 - 2010); Research Scientist, Texas A&M University (2010 - 2014), Associate Director-NSSPI (2014-2015). He has more than 28 years of experience in Nuclear Science and Engineering research, education and training with specialization in nuclear safety, security and safeguards. He teaches courses on nuclear fuel cycle and nuclear material safeguards, nuclear security, nuclear non-proliferation, and Monte Carlo radiation transport. Research interests include safeguards approaches for nuclear fuel cycle, proliferation resistance quantification & analysis, nuclear forensics, nuclear security insider threat analysis, fast breeder reactor analysis and small modular reactor neutronics coupling with thermal hydraulics. In current position, manages and directs projects funded by USDHS, USDOE, USDOS, the IAEA and nuclear utility companies. Has conducted nuclear security

educational programs in the U.S. and abroad for faculty and professionals. He has over 170 technical publications in referred journals (47) and peer reviewed (28) and other conference proceedings (99). He has supervised more than 34 MS thesis and PhD dissertation research of students (including 13 current students), most of them conducting research in the area of nuclear non-proliferation and neutronics. He has also supervised 5 postdoctoral research associates in the nuclear non-proliferation and nuclear security subject area.

M. Sai Baba
TV Raman Pai Chari Professor, NIAS

Prof. M. Sai Baba, Outstanding Scientist and formerly Director, Resources Management Group, Indira Gandhi Centre for Atomic Research and Senior Professor, Homi Bhabha National Institute. Presently holding the TV Raman Pai Chair Professor at National Institute of Advanced Studies. At NIAS he is currently working in the domains of Science and Risk Communication, Human Reliability Program and Understanding Ancient Indian Knowledge Systems for applying them for the holistic development of youth.

He did his postdoctoral work at Texas A&M University and was a Visiting Scientist at Research Centre, Julich, Germany. He has also spent time at Nuclear Research Centre (KFA), Julich as Guest Scientist under Indo-German Bilateral exchange program. He is conferred Doctor of Science (Honoris Causa) by Dr MGR University, Education and Research Institute.
Dr. M. Sai Baba has made significant contributions towards institution building and academic management and contributed to implementation of several high impact activities of relevance to Department of Atomic Energy. He played a pivotal role in starting the BARC Training School at IGACR and was heading the same till the time of his superannuation.

Amongst others he is a member of: High-level committee on S&T Institutional & Human Capacity Building, constituted by DST and Expert Committee, UGC- SERO, Hyderabad, Constituted by UGC

V. Nidhi
Project Associate (former), National Institute of Advanced Studies

A former researcher at National Institute of Advanced Studies, IISc Bangalore Campus and worked in the field of Human Reliability Program (HRP) in Industries of National Importance focused on the nuclear industries and added the knowledge of HRP or equivalent program(s) practiced at various countries. Currently Mrs. Nidhi has joined the CEA, France as an early-stage researcher in the field aiding nuclear dismantling and decontamination. Vagisha holds two Master's degrees in 'Nuclear Science and Technology' and 'Sustainable Nuclear Engineering: Application and Management'. She specializes in the Advance Nuclear Waste Management and radiation therapy and

additionally holds interest in the field of Nuclear Safety and Security. She taught at Department of Nuclear Science and Technology at Mody University of Science and Technology, Rajasthan for a year.

A.K. Shah
Project Associate, National Institute of Advanced Studies

Mr. Amit K Shah graduated (B.Tech + M.Tech, dual degree) in Nuclear Science and Technology in the year 2020 from Amity Institute of Nuclear Science and Technology, Amity University, Noida, UP. He has done internships in the premier research institute of India. He had hands-on experience in radiation detectors from institute Atomic Mineral Directorate (AMD), Delhi; Saha Institute of Nuclear Physics (SINP), Kolkata, West Bengal and the Department of Physics and Astrophysics, Delhi University, Delhi. He also has experience as an intern in the Nuclear Medicine department of Max Hospital, New Delhi, India. He presented a paper on "SMR: Green, Compact, and Innovative Alternative" at the International Nuclear Material Management Conference, 2020. He did his Master thesis project on "Parametric study of thermal Molten Salt Reactor" at Bhabha Atomic Research Centre, Mumbai, India." Currently he is working in the domain of Human Reliability Program at National Institute of Advanced Studies.

Summary of the Second Meeting of the Core Group on Human Reliability Program in Industries of National Importance

The participants of this meeting are essentially the same as those who participated in the first meeting of the core group held in October 2019. Dr. N. Ramamoorthy, Ms. V. Nidhi and Mr. A.K. Shah are the three new additions. Ms. Nidhi worked as a project associate in NIAS on this HRP project until 30th September 2020 and Mr. Shah is currently working as a project associate in the HRP project at NIAS. Due to the restrictions imposed by COVID, the meeting was conducted on the virtual platform. The meeting was conducted during 16.00-18.15 hours (Indian Standard Time) on 14th and 15th October and during 15.00-17.15 hours (Indian Standard Time) on 16th October.

1. The meeting started with a welcome by Prof. Sai Baba and Dr. Chirayath followed by the self-introduction of the participants.
2. Prof. Sai Baba's presentation was the first in the meeting and he gave the summary of the meetings held earlier in April 2019 and October 2019. He recalled about the objective of the first meeting held in April 2019 where various elements for HRP were discussed bringing together Indian and U.S. subject matter experts. The focus was on identifying good practices in safety and security concerning HRP. Based on the recommendation of the first meeting a core group to discuss in detail about various elements of HRP in the industries of national importance was formed. The core group had its first meeting in October 2019 which discussed various aspects of HRP like, Evaluation of elements of HRP, Continuous Evaluation, Human Factors in Nuclear Power Plants, Challenges in HRP Analysis, Augmenting HRP employing Human Centric Design, Accident Causation: Role of Active and Latent Failures, HRP and Technology Disruption, Importance of Good practices and Human Reliability, Relevance of HRP: The Role of Academic Institutions.

   Prof. Sai Baba also briefed about the summary of the panel discussion held on the theme "HRP In Indian Context" during the meeting:

   a) Create a database on human performance, Document steps taken that avoided failures/near misses, Identify active errors but also latent errors.
   b) HRP should create opportunities for managing the unforeseeable circumstances in workplace.
   c) Ways to automatically capture an individual's disruptive behavior as soon as possible at the workplace.
   d) Move from Human Reliability to Human Validity.
   e) Importance of Cultural, socio-economic aspects.
   f) Need for academic curriculum development in human factors.

Discussion:

Prof. Ramamoorthy said the pandemic added an extra element to HRP in addition to the factors which had been discussed and it is the factor of surprise (frustration, depression, angst, etc.) which

has affected all the industry and nation as well. Mr. Satyanarayana said that the employee should be kept happy that way human error can be minimized. Also capturing near-miss accident and failure modes can enhance HRP. He also added that in the nuclear Industry training through simulation should be given more importance. Dr. Kallol Roy added that the training aspect is very important and training in the nuclear industry supports prevention of failures. He also said that human reliability can be improved by giving advanced tools to operators to minimize human error.

Mr. D.K. Shukla emphasized recording success rate will support in improving human reliability. The definition of human reliability should be changed because it is defined in terms of unreliability. He further added that Human behaviour is complex, and it cannot be broken down into components and we can only predict the human reliability to a limit beyond that it is not possible. Regarding the human error, he said we should not simply replace humans with machine-based upon their error. We should analyse the mistake rather than replacing them with the machine. Another interesting point he made was about having a centralized database rather than having database for the different industries as this will make access to data easy.

3. Prof. Chirayath has summarized the work carried out by the NIAS-Texas A&M team on the topic "A review of Human Reliability Programs (HRP); Trustworthiness Program; Personnel Reliability Program of various counties". HRP components of the programs of seven countries (Finland, the UK, USA, Japan, Russia, Nigeria, Jordan) were analyzed and compared. Also, trustworthiness recommendations of the International Atomic Energy Agency (IAEA) were compared. Some of the variations seen are: no specific mention about drug test and behavioral observation in Japan, Nigerian program emphasizes on drug and alcohol test in increased frequency with sanctions being severe for violating personnel, Jordan practices security culture self-assessment and anti-corruption measures are emphasized in Russia. He mentioned that a journal manuscript is under preparation for submission on this comparative study to understand good practices in HRP practiced in various countries, including those with societies like that of India.

Discussion:

Mr. Satyanarayana recommends proper background checks such as financial checks to add to the recruitment process to enhance human reliability. He also suggested making the recruitment process transparent.

Prof. Mandal discussed the difference between human error and human bias where he says human bias is reversible errors and errors are reversible biases suggesting that the humans cannot be made free from error.

4. Ms. Vagisha Nidhi made presentation on the topic "Rules of conduct for employees working in the Indian central governmental organization". She emphasized on what set of actions are allowed and practices followed in central government organizations in India. She referred to rules like notification of personnel's recurring financial responsibility, an update of possession of the significant asset(s), reporting repeated absenteeism, alcoholism at the workplace.

5. Mr. Seshaiah talked on the topic "Training/Retraining in Nuclear Power Corporation of India". In his talk he discussed about the category of employees in NPCIL: Technical persons, i.e., Senior Management, Engineers (Scientific Officers), Supervisors (Scientific Assistants/Foreman), Technicians, and Contractor Employees. He mentioned about the procedures followed for recruitment at entry level for Engineers/Scientific officers and supervisors. For Engineers/Scientific officers – Graduate engineering degree (Mechanical, Chemical, Electrical, Instrumentation, Electronics, Civil, Industrial Safety, Fire Safety, and Computer Science). For supervisors they should have diploma in Mechanical, Chemical, Electrical, Instrumentation, Electronics, Civil and Computer Science engineering. Senior management positions are taken up by people growing from inside the organization and there are no direct recruitment processes. The training process is conducted against approved structured syllabus and procedure which is also known as Induction training. In induction training engineers spend 3 months in classroom training on Nuclear engineering subjects and other subjects against approved syllabus and then they spend six months training at a reactor sites depending on the reactor stream. The supervisor candidates spend six-month classroom training and one year on the job training.

6. The second day started with the presentation by Mr. Shah on "the Role of Background check-up and continuous monitoring". He presented about how pre-employment screening helps mitigate an entity's personnel security risks, which can be done through: education verification, checking the criminal record, financial record, work history verification, and security orientation. He also highlighted the importance of continuous monitoring to provide greater assurance for designated positions in an organization.

Discussion:

There was discussion about the checking the financial transactions and background of employees working in the government run organizations. (i) all the government employees had to file their property returns every year, (ii) at the time of joining a government job each one must declare their property.

Mr. Satyanarayana, informed about the procedures in place for the need for the employer to inform the administration about acquiring movable and immovable properties beyond a value, the report of which is sent to the head office on quarterly basis. Also, there are procedures in place, where in if any employee is found not to perform his duties, the employee is sent for retraining.

Dr. Ramakumar gave an instance where in his organization they received a few complaints from outside organizations that one of their employees was in severe debt and was vulnerable to being influenced by other factors. He also raised a point mentioning that we are only evaluating the supervisory staff, management at entry and middle level. There is a need for having procedures for monitoring people across the management levels as the health of the organization depends on all.

Dr. Chirayath recalled prospective employees contacting him regarding his student's background check in the US. He also mentioned when an employer hires someone, the employer has his/her

financial information such as open lines of credit score, loans, outstanding balances, bankruptcies etc. He pointed out that a person may not be employed if they are not financially stable. He further added that a supervisor or a lower-class employee in an HRP certified position who has access to critical information can be removed, no one is an exception, anybody is subject to evaluation.

Dr. Ramamoorthy indicated that the management styles vary with industry type so our approach towards the HRP must be different according to the industry. Prof. Sai Baba indicated that studies are being carried out various aspects of HRP which would be useful across the organizations.

Dr. Xavier Raj queried whether there is any data/research on connecting entry-level checks and other parameters to the human reliability program in certain industries. Ms. Nidhi mentioned about the availability of documents detailing well-defined procedures for the initial screening.

Mr. Satyanarayana brought out the need for restricting the working hours of individuals on shift duty in the nuclear industry.

7. The next presentation was made by Prof. Mandal on the topic "Malicious insider: Personality features and behavior indicators".

   Prof. Mandal discussed about emotional bias and talked about the hazards of malicious insider and techniques to identify insider threats. He then went on to talk about profiling where he mentioned that generally candidates are hired on the basis of aptitude and not attitude. In profiling, he talked about personality type: psychopath, narcissist, and Machiavellianism. To identify them, behavior signature analysis can be done which includes analyzing facial expressions, vocalics, etc. The detection is based on identifying and analyzing the micro-expression as they happen too quickly for the brain to have control on it. The deception also can be identified through analysis of walking gait, voice tone, and dilation and contraction of pupil. It is important to identify those with malicious intent as they can influence the vulnerable employees into doing malicious acts.

Discussion:

The discussion began with the question "Do we have proper tools to do the initial screening?" and Prof. Mandal answered that the technology is available like polysat situation judgment test. Mr. Seth indicated that Artificial Intelligence could play a very important role to identify malicious insider during initial screening. Technologies are becoming available and organizations have started using them.

8. The next presentation was made by Ms. Kanagalakshmi on the topic "Personal Access Control System including Contractor Work Force."

   Ms. Kanagalakshmi talked about the challenges, especially during construction stage, on implementing the security and safety culture. These challenges include: less manpower deployment, literacy/level of understanding, a large number of the migratory population during the construction phase and

language barriers. She briefed about the procedures for access Control, Authentication (personal photo, identity proof, age proof, police verification, etc.), Authorization (online monitoring, surveillance, graded approach, etc.), and Audit (accountability, verification, record, etc.) and role-based access. And the components of Personnel Access Control which are Administrative (roles, procedures, awareness, auditing, monitoring), Technical (biometrics, accounting, smart cards), and Physical (guards, fencing, locked doors, CCTV, motion detectors, smoke detectors).

Discussion:

Mr. Seth started the discussion by asking how the access control system is linked to safety work permit system for contract laborer. Replying to the query Ms. Kanagalakshmi said that the building is compartmentalized, and they have access control in each compartment through a biometric system that can be used to access the compartment. So, if contract labor wants to enter a building, they will be sent to a concerned IT section and then they will be able to access based on Radio-Frequency Identification (RFID) based access system. In the case of contract laborer, the contractor must give the names first against that particular safety work permit that these are the people who are going to work. Dr. Ramakumar suggested her to incorporate HRP during construction stage.

9. The next presentation was made by Mr. Shah on "Annual medical examination and health monitoring"

   He detailed about the medical examination done for HRP positions in the US. His presentation included the importance of medical assessment which is done to evaluate and to check the ability of an HRP candidate to perform assigned duties in a reliable and safe manner. He talked about the responsibility of the designated physician and the importance of continuous health monitoring and the activity of the HRP-certified individual.

Discussion:

It was indicated that the medical examination is done in the plants as per the Indian Atomic Energy Regulatory Board guidelines.

10. Day 3 discussion started with the presentation by Dr. Xavier Raj on the topic "Safety culture: Human-Centric Approach"

    He talked about the culture of a nation and its components divided into six dimensions: Power distance, Individualism, Masculinity, Uncertainty, Avoidance, and Long-term orientation. He discussed about the difference between organizational culture and safety culture. Organizational culture is "the way things are done around here" and safety culture is generally a set of attitudes and practices that emphasize safety over competing goals such as production or costs. He mentioned how the electricity department of France moved from a technical mindset to putting humans as the center in terms of ergonomics. He emphasized the attributes in the HRP document help: define, translate, and communicate safety culture for people to adapt to their culture. He referred to the fact that the safety processes are not done as a routine exercise in France. A team of anthropologists, psychologists, communication specialists were brought together to develop a safety culture.

Discussion:

Prof. Chirayath referred to an IAEA document describing security culture model (Edgar Schein model), having three layers: beliefs and attitudes; principles for guiding, decision, behaviors; and goal meeting. He gave an example of Jordan where self-assessment is done at the employee level. Manger level and management level, which is a survey prepared by the IAEA.

Mr. Satyanarayana indicated that in all the NPCIL sites, they adopt a procedure of circulating a questionnaire to the employees and based on the response the weakness domains are identified and efforts are taken to improve them.

11. The next presentation was by Prof. Sai Baba on the topic "HRP challenges: Identify the components for implementing in the industries of National importance".

He talked about the industries of National importance, industries which would have implications beyond the geographical boundaries of the industry which will affect the environment and people around. The HRP helps address safety, security, and possible sabotage but while addressing it is important to ensure that it would not impact productivity and quality assurance. He mentioned different industries such as nuclear, aviation, chemical, mining, and transport and the challenge to find the common thread in all of them.

Discussion:

Dr. Ramamoorthy suggested that there are some industries where a personnel check is required in the initial screening. Rather than stringent laws on all the employees, it would be better to identify the individual who could cause problems and then put the individual through some tests.

12. **Discussions on topics dealt with in the meeting**.

Dr. Ramakumar said that we cannot completely rely on the machine and hence human intervention is very important.

Prof. Sai Baba said that the technology can be used for identifying but the ultimate decision had to be left to human(s).

Dr. Xavier Raj indicated about the availability of methods for detecting any devious behavior using sophisticated sensory equipment and algorithms that can identify patterns and mentioned about the triangulation method to detect any anomaly. The industries are now converging and giving a new framework to work upon, and we need to look at it.

Mr. Seth said that medical examination in initial evaluation is followed in chemical industries and many other industries. He added that artificial intelligence can be used to identify devious behavior, which could cause harm to the industry and the need to enlist the help of technology.

Mr. Shukla mentioned that he was happy that the discussion have arrived at a balance, i.e., how much attention should be given to the machine and how much attention should be given to reliability of humans. He stressed on the importance of having a national database for human performance and human reliability.

Dr. Xavier Raj brought out the lack of information in the public domain relating to safety incidents in various industries.

Mr. Satyanarayana mentioned that World Association of Nuclear Operators (WANO) and INPO (Institute for Nuclear Power Operations) made available documents regarding human reliability. He mentioned that the role played by WANO in improving the performance in operating nuclear reactors and suggested that similar approach to be adopted for other industries. He also mentioned that there is a need for identifying the non-performers and rewarding the good performers. He referred to ODM (Operator Decision Making) being adopted to help the industry.

Dr. Kallol Roy indicated about the automation coming in aid of operators and the importance of bringing synergy between the humans and machines.

Dr. Kazi brought out the importance of providing access to credible information relating to safety and security procedures being adopted in the industry.

Mr. Seth pointed out the role think tank organizations like NIAS should and can play in coming out with documents summarizing the procedures of HRP in the Indian context, which can be of use to various industries of national importance.

Discussions ended with the importance of taking the work forward and coming out with documents to serve as reference material addressing the human reliability issues of safety and security.


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Document control sheet

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11. **Abstract:**

HRP is widely used in the sectors requiring high standard of safety and security. As part of collaborative research between NIAS adn Texas A&M University, a discussion meeting was organized at NIAS bringing together national and international experts from diverse industries of national importance to deliberate on HRP subject matter. Further a core group was formed to further discuss on the theme and two meetings of the core group were conducted. Report of the discussions held in the three meetings is presented.

12. **Keywords:**

Human Reliability Programme, Safety, Security, Industries of National Importance

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National Institute of Advanced Studies

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