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Luciano Maiani
Raymond Jeanloz
Micah Lowenthal
Wolfango Plastino *Editors*

# International Cooperation for Enhancing Nuclear Safety, Security, Safeguards and Non-proliferation

## Proceedings of the XXI Edoardo Amaldi Conference, Accademia Nazionale dei Lincei, Rome, Italy, October 7–8, 2019

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Luciano Maiani · Raymond Jeanloz ·
Micah Lowenthal · Wolfango Plastino
Editors

# International Cooperation for Enhancing Nuclear Safety, Security, Safeguards and Non-proliferation

## Proceedings of the XXI Edoardo Amaldi Conference, Accademia Nazionale dei Lincei, Rome, Italy, October 7–8, 2019

Keynote Speeches by
Mohamed ElBaradei–IAEA Director-General Emeritus
Fabiola Gianotti–CERN Director-General

Accademia Nazionale dei Lincei NATIONAL ACADEMY OF SCIENCES Springer Open

*Editors*
Luciano Maiani
Department of Physics
Sapienza University of Rome
Rome, Italy

Raymond Jeanloz
Department of Astronomy
University of California Berkeley
Berkeley, CA, USA

Micah Lowenthal
Committee on International Security
and Arms Control (CISAC)
The National Academies of Sciences,
Engineering, and Medicine
Washington, DC, USA

Wolfango Plastino
Department of Mathematics and Physics
Roma Tre University
Rome, Italy

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# Preface

On 7–8 October 2019 at the Palazzo Corsini in Rome, the Accademia Nazionale dei Lincei and the US National Academy of Sciences convened the XXI Edoardo Amaldi Conference with the patronage of the Italian Ministry of Foreign Affairs and International Cooperation and with support from the National Research Council (CNR), National Institute of Nuclear Physics (INFN), Istituto dell'Enciclopedia Italiana Treccani and the National Academy of Sciences Thomas Lincoln Casey Fund. At the Conference, a diverse group of experts, eminent scientists, diplomats and policy makers met to discuss challenges facing the international community related to nuclear safety, security, safeguards, non-proliferation, and arms control, as well as ideas for addressing those challenges. Speakers included the Presidents of the Italian and US Academies of Sciences, five Nobel Laureates and Nobel Prize awarded organizations, directors of international scientific organizations, leaders of non-governmental organizations (ICAN and Pugwash), and nuclear experts and officials from Argentina, CERN, China, CTBTO, the European Commission, France, IAEA, Iran, Israel, Italy, ITER, NATO, Pakistan, the Republic of Korea, the Russian Federation, the UK, the United Nations, and the USA.

The premise of the two organizing groups in the Academies, the Gruppo di Lavoro per la Sicurezza Internazionale e il Controllo degli Armamenti (SICA) and the Committee on International Security and Arms Control (CISAC), is that scientists can play important roles in reducing risks and solving problems. Scientists have a shared language and approach to reasoning and analysis, and they have relationships arising from the international nature of science, so they can sometimes make unique progress on diplomatic issues with technical dimensions and technical issues with diplomatic dimensions. The Amaldi Conference brings together officials who are responsible for addressing these international security issues and is structured both to promote public awareness through the opening sessions broadcast by RAI News and RAI Cultura, and through closed sessions among participants, meant to encourage discussion. Productive side discussions among parties that might not otherwise talk are key products of the Amaldi Conference, and those are needed now as much as they ever have been.

The international security environment is in flux: many national governments have turned attention to domestic interests, questioned the international order and even conducted military incursions into other nations' territory. Militant groups have proven to be resilient and willing to break fundamental norms. Meanwhile, stabilizing influences such as treaties and international organizations are eroding through diminished support.

More specifically, as the USA has expressed and acted on scepticism about treaties, alliances and international organizations. NATO faces unprecedented internal political conflict, and Russia has renewed its assertiveness in European and Middle East affairs. China has established partnerships and flexed political muscle in South Asia, Southeast Asia, Africa, and in international forums while also exhibiting military strength while claiming domain over international waters. With the termination of the Treaty on Intermediate Nuclear Forces in 2019 and the sunset of the New Strategic Arms Reduction Treaty in early 2021, there is a real prospect of the end of nuclear arms control treaties between the world's two largest possessors of nuclear weapons. Impatient with the pace of disarmament and motivated by moral concerns, the International Campaign to Abolish Nuclear Weapons (ICAN) and 80 countries (as of this writing) have supported ratification of the Treaty on the Prohibition of Nuclear Weapons. Pakistan continues to increase its nuclear arsenal and espouses a policy of nuclear first use on its own territory in case of invasion, while India reaffirms its conventional military strength and, decrying terrorist attacks launched with impunity by groups in Pakistan, says any nuclear use against Indian forces could result in nuclear reprisal. North Korea is repeating its pattern of dangling the prospect of denuclearization and simultaneously threatening resumption of missile and nuclear tests. With the US Withdrawal from the Joint Comprehensive Plan of Action, Iran is stepwise reducing its commitment to the agreement. The Middle East has seen chemical weapons used on civilian populations by both the Syrian government and terrorist groups, groups that have persisted in Syria and Iraq despite overwhelming conventional forces fighting against them. The widespread re-emergence of nationalism and narrow definitions of national interests underlies and runs through this dangerous set of developments.

These issues and the puzzle of how to benefit from the peaceful uses of nuclear energy, as well as the intersection of basic scientific research with science diplomacy and the challenges of international security, were addressed throughout the conference. Nobel Peace Laureate Mohamed ElBaradei and CERN Director-General Fabiola Gianotti gave keynote talks and participants heard remarks from Izumi Nakamitsu, United Nations Under-Secretary-General and High Representative for Disarmament Affairs, Federica Mogherini, High Representative for Foreign Affairs and Security Policy—Vice-President of the European Commission, and Paul Richard Gallagher, Secretary for the Holy See's Relations with States.

We, the Editors, are pleased to present this volume capturing these remarks and papers from each of the sessions. We thank the President of the Accademia Nazionale dei Lincei, Prof. Giorgio Parisi, and the President of the US National Academy of Sciences, Dr. Marcia McNutt, for their fundamental support to this conference. Moreover, we thank the Director General of the Accademia Nazionale

dei Lincei, Dr. Angelo Cagnazzo, and International Relations Officials, Marco Zeppa, Pina Moliterno, and all Lincei staff, as well as Hope Hare and other staff and leadership of the US National Academies of Sciences, Engineering, and Medicine, and finally the Authors and Session Chairs for their efforts, which made the conference so successful.

Rome - Washington DC
15 December 2019

Luciano Maiani
Chair
International Security and Arms
Control Working Group
Accademia Nazionale dei Lincei

Raymond Jeanloz
Chair
Committee on International Security
and Arms Control
US National Academy of Sciences

Micah Lowenthal
Director
Committee on International Security
and Arms Control
US National Academy of Sciences

Wolfango Plastino
Scientific Secretary
International Security and Arms
Control Working Group
Accademia Nazionale dei Lincei

# Keynote Speeches

**Mohamed ElBaradei and Fabiola Gianotti**

## Security and Prosperity in Changing Times

Mohamed ElBaradei
International Atomic Energy Agency, Vienna, United Nations
e-mail: elbaradei@iaea.at

It is an honour for me to speak at this venerable Academy. The world recognizes Italy as the birthplace of the Renaissance that ushered us from the middle ages into modernity and humanism. Not many are aware, however, that Italy is also home to numerous twentieth-century prominent scientists. Enrico Fermi, Edoardo Amaldi, Rita Levi Montalcini and Carlo Rubbia to mention a few. They were among those who pushed the frontier of our understanding of nature and ourselves. I am privileged to have had the opportunity to interact personally with some of them.

Our recent achievements in fields like health and medicine, communication and artificial intelligence are incredible. Nonetheless, I am sure that we all agree that our ability to steer these achievements towards peace and prosperity falls short. In terms of peace, we continue to rely on force to settle our differences, and we rely for our "ultimate security" on a system, "Mutual Assured Destruction" (MAD), that carries the seeds of self-destruction. In terms of prosperity, there are around 800 million people living in extreme poverty and *sub-human* conditions. We certainly have a long way to go.

The advent of the technological revolution, similar to the renaissance, gives us a unique opportunity to herald a new age. The instruments of change available to us and the speed by which we can affect change are overwhelming. However, we need to be clear where we want to go, make the right decisions and ensure that we humans remain in the driver seat. This is the responsibility of all of us: scientists, ethicists and policy makers. We have to step up to the plate and put our heads together. In this, equity, cooperation and empathy are indispensable.

Let me start with the quest for prosperity, specifically what the nuclear community could do. Energy is a key requirement for development. Every aspect of our basic needs depends on it. It is unacceptable to let alone morally repugnant that around 1.1

billion people have no access to electricity, the majority of them in sub-Saharan Africa. We know that nuclear energy is a clean source of energy, a highly valuable asset at a time of climate change crises. Yet its share in the global electricity supply is shrinking. It was 14% in 2011 and is today around 11%. It is projected to decline to around 3–7% by 2050. The chief reasons being serious concerns among the public about the possibility of radiation contamination resulting from a serious accident and fears regarding the safe disposal of high-level radioactive waste.

Unfortunately, the international community is in the habit of recognizing warning signs only *post-mortem*. This has been the case with safeguards (after Iraq), nuclear security (after 9/11) and nuclear safety, where we opted to ignore the canary in the coalmine. Both after Chernobyl and Fukushima Daiichi, there was a rush to strengthen nuclear safety through conventions, standards and review missions. Nevertheless, nuclear safety is still considered solely a national responsibility, despite the likely trans-boundary impact of a severe nuclear accident. Could we start thinking of nuclear safety not merely as a national responsibility but a global concern and embark on legally binding safety standards and safety reviews? I should mention here that the IAEA statute considers Agency "safeguards" to cover both safety and proliferation issues. Could we also agree that there is an urgent need for an international nuclear security architecture in which all states adhere to IAEA recommendations and guidelines and put in place appropriate national security frameworks?

Looking to the future, can scientists enable us to move to the next generation of nuclear energy? Can they help us through fusion, described as the silver bullet for energy scarcity and climate change, to generate abundant, safe and clean power and move to a carbon-free economy? Recent news from ITER, the world's largest nuclear fusion experiment sends an optimistic message: we are six years away from the "First Plasma".

Can we soon see an operational high-level waste disposal facility to assure the public that there is actually a safe technical solution to the waste issue? Finland has started construction of permanent repositories for high-level waste and spent fuel and the process of selecting a site is underway in other countries, Sweden and France among them. It would be quite reassuring to see the first waste repository commissioned in the not so distant future.

I turn now to peace including nuclear arms control and non-proliferation. There is no denying that the status quo is very depressing. Experts everywhere agree that the nuclear threat is more dangerous than at any time since the Cuban missile crises. The nuclear arms control regime is literally collapsing with the only remaining treaty expiring in a couple of years with no talk of renewal. All nuclear weapon states are in a frenzy to modernize their arsenals including developing hypersonic delivery systems and usable low-yield nuclear weapons. Moreover, all are engaged in a blame game with no sign of reversing course.

Is it difficult to comprehend that the nuclear arms race is not a zero-sum game and that we are all doomed in any nuclear conflagration by design or accident? Is it difficult to fathom that a discriminatory arms control system based on haves and have nots is not sustainable? Is it difficult to foresee that a state facing a real or perceived security threat might be tempted to imitate the "big boys" and try to acquire the very same weapons the weapon states are relying on while admonishing others not to have?

In addition, how about the legal commitment to nuclear disarmament that all the major nuclear weapon states entered into five decades ago which was an integral part of the NPT? How does this obligation square with recent statements by some nuclear weapon states and others, who expressed their opposition to the Nuclear Weapon Ban Treaty because inter alia "the policy of nuclear deterrence has been essential to keeping the peace … for over 70 years"! How does this about face affect the integrity of the non-proliferation regime? Could the weapon states at least show some serious commitment to their disarmament obligations by taking certain measures in that direction? For example: getting the CTBT into force rather than mulling over testing new weapons? Negotiating among themselves the modalities for their collective adherence to the Nuclear Ban Treaty (TPNW)? Resuming negotiation of the Fissile Material Cut-off Treaty stalled in the Conference on Disarmament for nearly 25 years?

And what about the idea of adopting a multilateral approach to the nuclear fuel cycle, uranium enrichment and plutonium separation, to have better control of the production of weapon usable material? A few years ago, when I introduced the idea there was excitement and a slew of proposals for assurance of nuclear fuel supply, resulting in the establishment of an IAEA low enriched uranium bank in Kazakhstan and a low enriched fuel reserve in Russia. Unfortunately, the principal idea of a multilateral approach to the fuel cycle, like many other ideas relating to nuclear arms control, has been dormant ever since.

I should also mention the crucial role of verification or safeguards in the current and future arms control regime. The adage "trust but verify" remains a truism and a key ingredient of any successful arms control effort. Yet a credible verification regime requires an appropriate legal mandate, adequate financial resources, up to date technology, including independent analytical tools and satellite monitoring, impartial inspectors and "safeguards" against outside meddling or interference. In most, if not all, these areas, the current international system could benefit from certain improvements to ensure robustness and integrity.

Scientists have a critical role in all this. Can they develop technology to combat cyber-attacks on command and control systems? Can they engineer an alternate command and control system to delay or prevent the so-called prompt launch where leaders of nuclear weapon states have less than ten minutes to respond to a reported nuclear attack?

Our principal challenge is to preserve what remains of the nuclear arms control architecture and strive to build new multilateral arrangements that bring under control the terrifying new technologies such as hypersonic delivery systems, nuclear-powered missiles and weapons in space. In parallel, we need to start discussion and research on a security system that does not rely on nuclear weapons. What will it look like? What are its basic elements? How is it going to work?

The few areas I briefly touched upon show that we are not short on ideas for a more secure and prosperous world. It is our mindset that is holding us back; the refusal to understand that the existing paradigm cannot last and that the obscene inequality and increasing polarization between and within nations lead to violence and wars. We seem to be stuck in the past, unable to recognize that the world has fundamentally changed and that we must think and act differently, as the young generation keeps reminding us if we want to preserve our planet and its inhabitants.

The late J. Robert Oppenheimer, one of the fathers of the atomic bomb, remarked after the first bomb was successfully detonated that "we knew the world would not be the same" and said that it brought to mind words from the Hindu Bhagavad Gita "now I am become Death, the destroyer of worlds". This was over seven decades ago! It is about time that we extricate ourselves from this foreboding scenario and move to a more humane one based on equity, cooperation and solidarity, basic human values that are central to our survival and well-being. We have the tools and resources at our disposal. I end by rephrasing the Russell–Einstein Manifesto of 1955 and the Normandy Manifesto of 2019: shall we put an end to the human race or shall we renounce war and abolish nuclear and other weapons of mass destruction? The choice is ours.

## Science for Peace

Fabiola Gianotti
European Organization for Nuclear Research, Geneva, Switzerland
e-mail: fabiola.gianotti@cern.ch

I am very pleased to have the opportunity to talk about Science for Peace at this conference, in particular by presenting two brilliant examples of successful collaboration across borders: CERN, the European laboratory for particle physics based in Geneva, Switzerland, and SESAME, the Synchrotron-Light for Experimental Science and Applications in the Middle East, based in Allan, Jordan.

Let me first share with you some thoughts about what Science can do for Peace.

Science can play a key role in connecting people in today's fractured world because it is universal and unifying. Science is universal because it is based on objective facts and not on opinions. The laws of nature are the same everywhere on earth, at any time in history.

Science is unifying because the quest for knowledge and the passion for understanding how nature works are aspirations and values that are shared by all humanity. Thus, scientific knowledge has no passport, gender, race or political party.

Another important role of science is related to the fact that we live in a society characterized by the fast growth of technology and innovation. While these developments have mostly positive consequences in terms of progress, they bring with them the risk of exacerbating inequalities, hence contributing to political and social unrest and widening the gap between developed and developing countries, the rich and the poor, those who have access to education and those who don't. Open science (open-source software, open hardware, publications in open-access journals, open data) and scientific education accessible to all play a crucial role in reaching out to the less privileged sections of humanity, thus contributing to capacity building and to reducing cultural and social gaps.

Last but not least, it is important that scientists contribute to the debates on the big societal and planetary challenges (e.g. the UN Sustainable Development Goals) by bringing facts and scientific evidence to the table. They should advocate scientific development as the foundation of progress against science-sceptical trends. They should make governments and society aware of the consequences of the possible misuse of scientific knowledge and technology and contribute to the development of adequate policies (e.g. on ethical issues, non-proliferation of weapons, etc.). And they should promote discussion at the global level and multilateral approaches. Scientific academies, in particular, can play a leading role in this context by bringing scientists and governments and policy makers together. Their impact is more significant when they join forces, as is the case with the present conference jointly organised by Accademia dei Lincei and the US National Academy of Sciences.

CERN, the largest particle physics laboratory in the world, is a brilliant example of what science can do for peace. CERN is an intergovernmental organization based on a treaty between Member States. Its mission is research in particle physics, the most fundamental of all sciences as it studies the elementary constituents of matter and the universe. Research at CERN has led over the decades to great discoveries, the latest one being the Higgs boson in 2012, and to the award of Nobel prizes to CERN scientists. CERN is also a driver of innovation. In fact, to accomplish its ambitious scientific goals CERN needs to build complex instruments in the fields of particle accelerators, particle detectors and computing infrastructure, and to develop cutting-edge technologies in various domains, from superconducting magnets to fast electronics, big data, cryogenics, etc. These technologies are transferred for free to society, for the benefit of everybody's lives. The most famous example of CERN's spin-off is the World Wide Web, which was developed at CERN in 1989 by Tim Berners-Lee and collaborators to facilitate the exchange of information among the Laboratory's scientists and was released in 1993 royalty-free for anyone to use and improve. Other CERN technologies today find applications in fields such as medical imaging and accelerators to treat cancer. The training of tomorrow's scientists and the scientific education of the general public are also part of CERN's mission and are achieved through a large number of initiatives that target, for instance, high-school students and teachers. Last but not least, and most relevant to this conference, CERN is a concrete example of peaceful collaboration across borders, as it attracts some 18,000 scientists from all over the world (more than 110 nationalities are represented).

CERN was founded in 1954, in the aftermath of World War II, on the initiative of visionary politicians and scientists (including Edoardo Amaldi) with the twofold goal of bringing back scientific excellence to Europe and promoting peaceful collaboration among European countries after the war. Hence, the concept of "Science for Peace" is enshrined in CERN's foundations. The CERN Convention, which was signed in 1953 by 12 European countries under the auspices of UNESCO, states that "The Organization shall provide for collaboration in nuclear research of a pure scientific and fundamental character … The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available…”. Thus, CERN’s Convention promotes scientific developments for peaceful applications (“no concern with work for military requirements”) and open science (“the results of its experimental and theoretical work shall be published or otherwise made generally available”), two extremely modern concepts whose spirit was already captured by CERN’s founding fathers.

The Convention also supports collaboration across borders (“the organization and sponsoring of international cooperation”) and training and education (“the dissemination of information and the provision of advanced training for research workers”).

Since its inception, CERN has played an important role in breaking political barriers, promoting in particular collaboration between scientists from eastern and western countries during the period of the Cold War. The first scientific contacts between CERN and the Soviet Union were established in the early the 1960s, and the first cooperation agreement between them was signed in 1967. According to this agreement, CERN would provide experimental equipment for a new accelerator being built at the Protvino laboratory in Serpukhov (near Moscow) and, in exchange, scientists from CERN’s Member States would participate in the scientific programme of the new accelerator. During the 1970s, several joint CERN-Soviet Union experiments were carried out at the Serpukhov facility and showed how scientific collaboration can surmount political obstacles even in a very tense international climate. Since then, several cooperation agreements have been signed between CERN and the Soviet Union, and later the Russian Federation, the latest one in April 2019. The relations between CERN and the countries of Eastern Europe have grown significantly, with many of these countries now having become the CERN Member States and some 1000 Russian scientists currently involved in CERN’s projects.

Today CERN has 23 Member States and 8 Associate Member States (including India and Pakistan). Membership is not limited to European countries, Israel being one of the Member States. Big countries that are historical partners of CERN, namely the USA, Japan and the Russian Federation, are Observers to the CERN Council (the body that governs the organization). In addition, CERN has signed some 50 international cooperation agreements, most of them with developing countries. For these countries, engagement with CERN is part of their efforts towards scientific and technological development and towards building a knowledge-based economy, as well as a channel to strengthen their relations with other countries. CERN’s annual budget amounts to 1.2 billion Swiss francs, and the Member States contribute to it in proportion to their net national income. Non-Member States, such as the USA, Japan and Russia, contribute à la carte, i.e. through one-off contributions to specific projects. It should be emphasized that budget stability over the decades and international cooperation have allowed extremely ambitious projects to be realized that no single country could have afforded alone.

CERN currently operates the Large Hadron Collider (LHC), the most powerful accelerator ever built. It is housed in a 27-km ring, which lies 100 m underground, across the border between Switzerland and France. It deploys the most advanced technologies in terms of, e.g. superconducting magnets. Operation started in 2010. Two beams of protons are accelerated in the two opposite directions of the ring up to the highest energies allowed by the technology and are brought into collision at four points of the ring, where four big experiments (ALICE, ATLAS, CMS and LHCb) have been installed in four huge underground caverns. The task of the experiments is to detect and measure the product of the proton-proton collisions with high precision. The detectors are high-technology instruments of spectacular size and complexity (ATLAS is about half the size of the Notre Dame cathedral in Paris and CMS weighs twice as much as the Eiffel Tower). Two years after start-up, on 4 July 2012, the ATLAS and CMS experiments reported the discovery of a new, very special particle, the Higgs boson.

These great achievements would not have been possible without the contributions of scientists from all over the world.

Today, some 18,000 scientists work at CERN. About 60% of them come from the Member States, some 2000 from the USA, 1000 from Russia and several hundred from Japan and China. CERN also hosts scientists from developing countries, such as Nepal, Mongolia and Madagascar. In this case, CERN's mission is to build capacity and help these countries to reduce the scientific and technological gap with other countries. Finally, some of the scientists involved in CERN's activities come from countries that are not the best of friends, e.g. Israel, Iran and Palestine. Yet, at CERN they work together, driven by the same passion for knowledge. About 50% of the scientists working at CERN are younger than 40, many of them Ph.D. students and post-docs.

CERN offers many training and educational opportunities for its young population, including regular "schools" of particle physics, accelerators, instrumentation and computing. Since 2010, some of these schools have been held in Africa every second year (in South Africa, Ghana, Senegal, Rwanda and Namibia so far), and are jointly organized with research institutions across the world. Every year, the CERN Summer Student Programme trains some 300 undergraduate students from all over the world, including a significant number from developing countries.

The CERN-UNESCO schools on digital libraries are an example of the application of CERN's open science for education and training. These schools aim to provide African librarians with the skills they need to run digital library systems, thus improving African researchers' access to information and increasing the global visibility of African research. They have been held in Rwanda, Morocco, Senegal, Ghana and Kenya so far and have been attended by 150 librarians from many African countries. The library system is based on INVENIO, an open-source digital platform developed at CERN.

Another brilliant example of science for peace is SESAME, the first facility for fundamental and applied research in the Middle East. It is based in Allan, Jordan. The Member States are Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey. Some of these countries would not sit around the same table for political discussions, yet at SESAME their scientists work together using the same research facilities and sit around the same table to discuss science. SESAME is an intergovernmental organization based on the CERN model of governance and scientific cooperation. CERN has also provided some of the accelerator components. Operation started in 2017, and the first scientific paper has been published recently.

Places like CERN, SESAME and other international scientific organizations cannot directly solve geo-political conflicts. However, they can break down barriers and help young generations to grow up in a respectful and tolerant environment where diversity, inclusiveness and collaboration are promoted as great values. They are shining examples of what humanity can achieve when we put aside our differences and disputes and focus on the common good. I believe that science can plant seeds of peace in today's fractured world.

# Tribute

**Wolfango Plastino**

## Tribute to Yukiya Amano

Wolfango Plastino
Roma Tre University, Rome, Italy
e-mail: wolfango.plastino@uniroma3.it

President Parisi, President McNutt
Chair Maiani, Chair Jeanloz
Her Excellency Ambassador Belloni
President Emeritus Quadrio Curzio
Director General Emeritus ElBaradei
Director General Gianotti

Excellencies, Ladies and Gentlemen,

I have the honour to deliver this Tribute to His Excellency Ambassador Yukiya Amano, who was Director General of the International Atomic Energy Agency (IAEA) between December 2009 and July 2019.

Ambassador Amano brought both professional expertise and personal values and commitment to his work, which resulted in a vision for the Agency. He had extensive experience in disarmament and non-proliferation diplomacy, as well as nuclear energy issues. At the Japanese Ministry of Foreign Affairs, Ambassador Amano was Director General for the Disarmament, Non-Proliferation and Science Department from 2002 until 2005. He previously served as a governmental expert on the United Nations Panel on Missiles and on the United Nations Expert Group on Disarmament and Non-Proliferation Education. Ambassador Amano contributed to the 1995, 2000 and 2005 Nuclear Non-proliferation Treaty Review Conferences, and he chaired the 2007 Preparatory Committee for the 2010 Nuclear Non-proliferation Treaty Review Conference.[1]

He was Japan's Resident Representative to the IAEA from 2005 until his election as Director General in July 2009.

[1]Cf. IAEA—Yukiya Amano's biography.

Ambassador Amano served as Chair of the IAEA Board of Governors from September 2005 to September 2006, and in that period, he received on behalf of the Agency the Nobel Peace Prize, shared with our keynote speaker, the distinguished IAEA Director General Emeritus Mohammed ElBaradei, with this motivation: “for their efforts to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way”.

Ambassador Amano changed the motto of the IAEA to Atoms for Peace and Development to better reflect the contribution of the Agency in assisting countries in the peaceful use of nuclear technology for their development.

After the Fukushima Daiichi nuclear power plant accident, he led the international effort to provide assistance to Japan and actively encouraged the Member States to learn the essential lessons from the accident. Ambassador Amano was an active proponent of the strengthening of nuclear safety standards throughout the world.[2]

In nuclear security, his efforts contributed greatly to the entry into force of the Amendment to the Convention on the Physical Protection of Nuclear Material. During his term of office, the International Conference on Nuclear Security became recognized as the leading forum for Ministers and other high-level representatives of IAEA Member States to consider this topic.[3]

In July 2015, Ambassador Amano signed a roadmap with the Islamic Republic of Iran for the clarification of possible military dimensions to its nuclear programme. At the same time, the Islamic Republic of Iran and the group of countries known as the P5—plus the European Union—agreed on the Joint Comprehensive Plan of Action, the JCPoA.

I also wish to recall the participation of Ambassador Amano and His Excellency Ali Akbar Salehi, Vice-President of the Islamic Republic of Iran and Head of the Atomic Energy Organization of Iran, at the 2017 Edoardo Amaldi Conference on 60 Years IAEA and EURATOM. On this very important issue, Amano said at that time.

[…] Even complex and challenging issues can be tackled effectively if all parties are committed to dialogue—not dialogue for its own sake, but dialogue aimed at achieving results. […] and quoting more […] the IAEA was able to make a vital contribution, and maintain the confidence of all sides, by sticking to its technical mandate and not straying into politics. […]

In that conference, Ambassador Amano gave examples of the IAEA’s work in helping developing countries to use nuclear science and technology in areas such as food production, electricity generation, the management of water supplies, protecting the oceans and responding to the effects of climate change and the human health and, in particular, cancer control by radiotherapy, nuclear medicine and imaging technology.

Then, my personal tribute. Let me express my deep gratitude because I had the honour to be appointed by Ambassador Amano as Member of the IAEA Standing

[2] Cf. Memorial Ceremony for Director General Yukiya Amano, Vienna, 21 August 2019.

[3] *Ibidem*.

Advisory Group on Technical Assistance and Cooperation with the purpose of advising the Director General on IAEA's technical cooperation activities in terms of their relevance, delivery and impact.

Throughout his tenure as Director General, Ambassador Amano, served the IAEA as well as its Member States with unwavering determination and commitment. His leadership of the international response in the aftermath of the Fukushima Daiichi nuclear accident, the modernization of the IAEA's nuclear applications laboratories in Seibersdorf and the increased international confidence in the credibility and impartiality of IAEA nuclear safeguards achieved during his tenure.[4] Then, in September 2019, the IAEA General Conference unanimously adopted a resolution to name a new facility in Seibersdorf "The Yukiya Amano Laboratories".

Ambassador Amano leaves behind a strong legacy in every one of the IAEA's mission areas, be it non-proliferation, nuclear energy, nuclear safety, nuclear security or technical cooperation.

On behalf of the Honourary Committee, I offer my condolences to Ambassador Amano's extended family and the IAEA staff.

Please, stand for a moment of silence and may his soul rest in peace. Thank you.

[4] Cf. European Union Statement on the occasion of the IAEA Board of Governors, Vienna, 25 July 2019.

# Opening Addresses

**Giorgio Parisi, Marcia McNutt, Elisabetta Belloni, Izumi Nakamitsu, Federica Mogherini, Raymond Jeanloz, and Luciano Maiani**

## Opening Address of the Accademia Nazionale dei Lincei

Giorgio Parisi
Accademia Nazionale dei Lincei, Rome, Italy
e-mail: giorgio.parisi@lincei.it

I have the great pleasure of opening the XXI Edoardo Amaldi Conference. I am grateful to the organizers of this conference, the Accademia dei Lincei, the US National Academy of Sciences. I am particularly happy to have here the President of the NAS Marcia McNutt. Her presence is a sign of the importance that our two Academies attach to their collaboration: I am sure that these relationships will increase in future.

We live in difficult and dangerous times: peace is at risk and the situation is worsening in recent years. This conference addresses points that are crucial for our future: it aims to understand how to set up international cooperation with the aim of enhancing Nuclear Safety, Security, Safeguards and Non-Proliferation. It is not an easy job, everyone wants Nuclear Safety and Security (at least for his own country): the non-proliferation treaty indicates very clearly in which direction we should move. Unfortunately, the implementation of this treaty has been very slow: in the treaty is written in a clear way that the nuclear states have the obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament. However, a general and complete nuclear disarmament is distant as ever and the governments of nuclear states do not have it on their agenda.

Which could be an exit strategy from this stalemate? The role of scientists may be crucial because they can be the link among people of different countries. Scientists are well accustomed to international cooperation, we all work together without paying attention to distinctions of race, nationality and so on: when we discuss science only technical argument do matter.

This scientific attitude of discussing a problem trying to use only logical argument may be a great advantage when we aim to reach an agreement during more difficult discussions where often arguments that seems rational have their deep roots in irrational feelings. Backchannel diplomacy may be successful in cases where Track One diplomacy has serious difficulties to progress: it helps the various actors to get a better understanding of the other actors.

Conferences like the present one are precious; I am pleased to acknowledge the contribution and the help of all the people that worked so hard for its successful realization:

– The Committee on International Security and Arms Control of the National Academy of Sciences and the Working Group on International Security armament control that worked together to prepare this conference.
– The two chairs Luciano Maiani and Raymond Jeanloz, the organizing committee of the conference Marvin Adams, Francesco Calogero, Steve Fetter, Micah Lowenthal, Alberto Quadrio Curzio, Carlo Schaerf and Edoardo Vesentini and the wonderful Scientific Secretary Wolfango Plastino.
– The speakers and the other participants to the conference whose the presence was crucial for its success: indeed, all the participants play an important role in spreading around the ideas discussed in the conference that hopefully should reach the governments of the various countries.
– Finally, the staff of the Accademia dei Lincei: the logistic organization was a rather complex task because there have been two days before a quite large event, the opening of the exhibition *Leonardo a Roma*.

I gratefully acknowledge the support from the Italian Minister of Foreign Affairs, from the National Research Council (CNR), from the National Institute of Nuclear Physics (INFN) from the Enciclopedia Treccani and from the public Radio Television Society (RAI).

## Opening Address of the US National Academy of Sciences

Marcia McNutt
US National Academy of Sciences, Washington, DC, USA
e-mail: mmcnutt@nas.edu

I would like to begin by saying “Thank you” to President Parisi for hosting us in this magnificent palazzo. It’s an honour to be here with you and your colleagues and to be able to join you in welcoming this distinguished group to the Twenty-first Edoardo Amaldi Conference, organized in a successful partnership between our two Academies.

The US National Academy of Sciences has a historic connection to the Lincei Academy. I hope that you will visit us in Washington, DC, and if you do, you will see a homage to the Lincei Academy. Our historic building was completed in 1924 when we were a young Academy—only 61 years old. In the Great Hall where all the assemblies of the Academy membership were held, artists created murals and decorations to inspire our scientists. In the arches above the galleries are renditions of the insignia of four of the world's oldest academies of sciences. The crowned lynx of the Accademia dei Lincei is in the east arch, reminding us of the scientific home Galileo Galilei, his accomplishments, and the importance of speaking truth to power.

There are problems and opportunities today that we as scientists need to address. We need to share what we know, to work together across political boundaries, to develop new technologies and apply novel strategies to help humanity preserve our very existence and, hopefully, improve the richness of the human experience. Climate change threatens people and ecosystems around the globe. Rapidly emerging bioscience offers enormous promise to eradicate diseases, but also potential risks of accidental and intentional harm. We convene today to talk about nuclear issues at a time of transitions when much is still unknown. We will talk about nuclear weapons and how to preserve security. About nuclear energy and how to promote safety and prosperity. And about nuclear science and how we together, joined by our quest for knowledge and our pursuit of the common interests of all, can do our part to make an increasingly divisive and dangerous world more connected and safe. Free, open and reciprocally beneficial collaborations among scientists around the world, based on transparent and mutually respectful interactions are essential to science and to science advice on these and other topics.

The National Academy of Sciences' Committee on International Security and Arms Control, CISAC, was formed nearly 40 years ago and engages counterparts in Russia, China and India in bilateral dialogues on all of these issues and more: space security, biosecurity, cyber-security and the implications of artificial intelligence in military systems. Composed of natural scientists, retired military leaders and policy and area experts, CISAC utilizes the common language of science and importantly the common understanding of evidence-based reasoning and how to establish facts. You have seen in the programme the history of the Amaldi Conferences and their connection to CISAC. We are proud to co-organize this conference and pleased to engage this broader group.

You will hear many talks over the next two days. None of us expects that this will be one harmonious song; there are real disagreements on these issues and we want to discuss them, not avoid them. Our organizations were formed on the premise that, if we begin with facts and apply scientific knowledge and reason, we can reach a better understanding of these disagreements and, in some cases, find solutions. At this conference, we will work to understand each other and to make progress towards solutions. I look forward to the discussions.

## Opening Address of the Italian Ministry of Foreign Affairs and International Cooperation

Elisabetta Belloni
Ministry of Foreign Affairs and International Cooperation, Rome, Italy
e-mail: elisabetta.belloni@esteri.it

Presidents, Chairpersons, Excellencies, Ladies and Gentlemen,

It is an honour for me to deliver this opening address to the twenty-first edition of the "Amaldi Conference" dedicated to International Cooperation for Enhancing Nuclear Safety, Security, Safeguards and Non-proliferation. The conference, organized by the Accademia dei Lincei together with the US National Academy of

Sciences, relies on the support of different national institutions, including the Italian Ministry of Foreign Affairs and International Cooperation.

I would like to associate myself in paying tribute to the legacy of Director General Amano. Thanks to his professionalism, unwavering commitment and skilful leadership, the International Atomic Energy Agency (IAEA) has further advanced along its pattern of "Atoms for Peace and Development" and is carrying out an impressive work to ensure security and safety of nuclear activities around the globe and to help countries achieve the goals of the 2030 Agenda for Sustainable Development. I am confident that the next Director General, under selection during these weeks by the members of the IAEA, will continue to lead effectively the Agency in a challenging environment.

I would also like to recall the memory of Edoardo Amaldi, whose studies on nuclear physics have greatly contributed to the design of particle accelerators. He was particularly engaged with our National Institute of Nuclear Physics and the European Organization for Nuclear Research (CERN). He stood among the most recognized nuclear scientists worldwide and joined the Pugwash Conferences on Science and World Affairs. I am particularly grateful to the Accademia dei Lincei for its commitment to the memory of such an important physicist and former President of the Academy itself.

The non-proliferation and disarmament community is currently engaged in the preparation of the next year Review Conference of the Non-Proliferation Treaty (NPT). In this regard, let me emphasize the importance Italy attaches to the NPT: it remains the cornerstone of the global non-proliferation regime and the essential foundation for the pursuit of nuclear disarmament, as well as the basis for further development of nuclear applications for peaceful purposes. In our views, these three mutually reinforcing pillars are still perfectly valid today.

It is with this approach that Italy is actively participating in the review cycle and is systematically emphasizing the substantial benefits, which the Treaty has so far ensured. In almost fifty years since its entry into force, the NPT has hugely contributed to strengthen the credibility of the non-proliferation norm. As a result of its legal obligations (Article III), almost the entire international community has safeguards arrangements with the Agency, which allow inspections to nuclear installations. Along the years the NPT has been remarkably successful in containing the number of states possessing nuclear weapons. And we have to jointly work to guarantee that despite all the challenges it remains successful.

In terms of nuclear disarmament, we are convinced that the best approach remains enshrined in the framework of Article VI of the NPT, which provides the only realistic legal framework to attain a world without nuclear weapons in a way that promotes international stability and based on the principle of undiminished security for all.

Our approach relies on the idea that the goal of a nuclear-weapons-free world can be gradually reached, implying the involvement of all relevant actors and through a series of concrete and progressive steps. In this regard, Italy has always been a staunch supporter of the entry into force of the Comprehensive Test Ban Treaty (CTBT) and has always strongly promoted the start of negotiations of a treaty prohibiting the further production of fissile material for nuclear weapons or other explosive devices.

Italy shares the widespread concerns about the catastrophic consequences of nuclear weapons' use and we are aware of the continuing nuclear risks for humanity. In this context, I believe that the International Community has to recommit to the concept of cooperative security, which over the decades, through effective strategic arms control agreements, has enhanced transparency, contributed to build confidence and substantially reduced stockpiles. We attach therefore the highest importance to the New START Treaty and would welcome early and active dialogue on its future post-2021 and on other arms control arrangements.

The reflection on the NPT brings me to address the severe stress, which the Joint Comprehensive Plan of Action (JCPoA) on the Iranian nuclear programme is currently experiencing. I would like to emphasize in this context that the JCPoA is a key element of the global non-proliferation architecture, whose implementation is of paramount importance. The Director General for Political Affairs and Security, Ambassador Cardi, will further elaborate on this issue, as well as on the serious North Korean proliferation crisis, in his address during the first Panel.

Italy will continue supporting the whole range of the IAEA's activities both financially, as the seventh contributor to the regular budget, and politically, also in its present capacity as a current member of the Agency's Board of Governors.

Italy highly values the vital role of the IAEA in strengthening capacities worldwide for the safe, secure and peaceful use of nuclear science and technology, in line with the 2030 Agenda for Sustainable Development.

Nuclear science and technology can be applied in a number of sectors, far beyond nuclear power, and in critical domains, such as medical therapy against tumours. In this respect, Italy is particularly committed to making the added value of nuclear science and technology available for the entire world.

We substantially contribute to the technical cooperation fund of the Agency, which helps countries across the globe to benefit from atomic technology for their own prosperity, and we host in Trieste the Abdus Salam International Centre for Theoretical Physics (ICTP), which is a driving force behind global efforts to advance scientific expertise in the developing world.

I am particularly pleased that each year a number of foreign researchers are hosted in national laboratories and medical structures in the framework of fellowships financed under the Agency's technical cooperation fund and managed in cooperation with the ICTP.

My country is also at the forefront of advanced research in nuclear science and technology, starting from the development of particle accelerators at the National Institute for Nuclear Physics and at the Elettra Sincrotrone Centre in Trieste. Let me also remind you about the Italian engagement for and within the European Organization for Nuclear Research. In this respect, I am particularly pleased that Director General Fabiola Gianotti is together with us today.

The Italian scientific community is particularly involved in state-of-the-art nuclear applications for nuclear medicine (e.g. the laboratories of the National Institute for Nuclear Physics) and for nuclear fusion (e.g. the involvement of the National Agency for New Technologies, Energy and Sustainable Economic Development in the ITER international project).

Let me finally conclude that Italy remains fully committed to the achievement of a better nuclear security environment and will continue to support all international efforts aiming at this outcome.

For the safety of its nuclear installations, Italy will continue to implement its national policy for decommissioning and safe management of spent fuel and radioactive waste in strict cooperation with the International Atomic Energy Agency. Just a couple of weeks ago Sogin—our national company for decommissioning—has been recognized by the IAEA as collaborating centre with the aim of sharing its expertise in international training programmes.

In terms of national regulation, I would like to recall that since more than one year the National Inspectorate for Nuclear Safety and Radiation Protection (ISIN) has been working as a new national regulatory authority, strengthened in its powers, independence, financial and human resources.

Presidents,
Chairpersons,

Let me thank you and your staff for the organization of this conference. The exceptional level of keynote speakers and panellists is a clear evidence of your success in preparing a debate, which I am confident will be fruitful, intense and thought-provoking.

Thank you for your attention.

## Opening Address of the United Nations Office for Disarmament Affairs

Izumi Nakamitsu
United Nations Office for Disarmament Affairs, New York, United Nations
e-mail: izumi.nakamitsu@un.org

Distinguished participants, Ladies and gentlemen,

It is a pleasure to address you as part of the Twenty-first Edoardo Amaldi Conference. I would like to commend the Accademia Nazionale dei Lincei for your commitment to nuclear disarmament and non-proliferation and thank you for organizing this event.

Since the first General Assembly resolution in 1946, the United Nations has made the elimination of all weapons of mass destruction one of its highest priorities. Yet today, that objective is under threat. The progress achieved in nuclear disarmament and non-proliferation, especially in the last thirty years, is being unwound. A qualitative arms race is underway as states that possess nuclear weapons modernize their arsenals. Key multilateral bodies are stalemated as differences over how to pursue disarmament grow wider.

The arms control framework that helped bring about the end of the Cold War is being eroded. The demise of the Intermediate-Range Nuclear Forces Treaty has, as Secretary-General Guterres cautioned, removed a vital brake on nuclear war. Should the so-called New START Treaty between the USA and the Russian Federation not be extended before its expiration in 2021 there will be no limit on the world's two largest nuclear arsenals.

These realities underscore starkly that a "business as usual" approach will not work. This is precisely why the Secretary-General launched a new vision for global disarmament in May last year in the form of his agenda for disarmament, "Securing Our Common Future".

The purpose of this agenda is to generate new momentum and partnerships that seek to tackle disarmament in a comprehensive manner and through the involvement of all stakeholders. It represents a call for concrete, practical actions, harnessing the capacities of the United Nations to support Member States in their endeavours to create a safer and more secure world across four distinct but mutually reinforcing pillars.

Let me highlight a few key aspects related to the first of these pillars, Disarmament to Save Humanity. The focus of this pillar is clear: to eliminate weapons of mass destruction and, in particular, nuclear weapons.

It appeals to all States to affirm that it is in the interest of national, collective and human security, as well as the survival of humanity, that nuclear weapons are never used again under any circumstances.

The total elimination of nuclear weapons can only be obtained through reinvigorated dialogue and serious negotiations between Member States to return to a common vision leading towards a world free of nuclear weapons.

As the Secretary-General advised the Conference on Disarmament earlier this year, what is needed is a new vision for disarmament, arms control and non-proliferation. One that secures the gains we have made and also tackles the challenges of the twenty-first century.

The upcoming 2020 Review Conference of the Treaty on the non-proliferation of nuclear weapons, marking the fiftieth anniversary of its entry into force, provides an important platform to move forward on these goals. I trust that States parties will make the most of this opportunity to consider how to ensure the future of the disarmament and non-proliferation regime.

As we look ahead, it is my hope that forums such as this one can help to invigorate dialogue and exchange, to overcome obstacles and to identify shared pathways and partnerships.

I look forward to working with you towards securing our common future and I wish you the best for your conference.

Thank you.

## Opening Address of the European Commission for Foreign Affairs and Security Policy

Federica Mogherini
European Commission, Bruxelles, European Union
e-mail: federica.mogherini@ec.europa.eu

Cari Amici, dear Friends,

Let me thank the Accademia dei Lincei for inviting me to this year's Amaldi Conference, and apologies for not being with you in person.

You opened the conference with a tribute to Amano, and I would like to thank you for this.

As you know, Amano and I worked very closely together, in these years, in particular on the implementation of the nuclear deal with Iran.

Thanks to the deal, the International Atomic Energy Agency has been tasked to monitor and verify Iran's compliance with its nuclear-related commitments—which is an incredibly sensitive and delicate task.

Amano carried out this task with professionalism and impartiality. The political pressure was immense, but he always focused exclusively on establishing the facts—leaving politics aside.

He set an example of personal integrity. But he also demonstrated how crucial it is for the world to rely on a multilateral institution such as the International Atomic Energy Agency—an independent, impartial and credible global institution.

Multilateral global governance is the best and only way to guarantee our collective security—and this should be self-evident when it comes to nuclear weapons.

Our non-proliferation architecture aims first and foremost at making our world a safer place. Dismantling such architecture would make the world a more dangerous place. It is a risk that none of us can afford.

So our first duty is to preserve the rules that we have built together and to work together for their full implementation.

I have mentioned the Iran nuclear deal, and the work we are doing to preserve it. I am just back from New York, where I gathered the Foreign Ministers of China, France, Germany, Russia, the UK and Iran, for a ministerial Joint Commission meeting. Together we confirmed that our goal is the full and effective implementation of the deal, by all sides, and preserving the agreement in these difficult times.

If all existing agreements were fully implemented, our world would already be a much safer place. I also think of the Intermediate-Range Nuclear Forces Treaty, or the entry into force of the Comprehensive Test Ban Treaty.

In the coming months and years the future of the Non-Proliferation Treaty, and of the New START Treaty, will be discussed too. This is all essential for our collective security.

So, the most urgent task is to avoid that the world moves backwards and prevent the worst from happening. But we must also prepare the ground for better times to come.

The way forward is multilateralism. From North Korea to the Middle East, only a multilateral framework can help achieve sustainable solutions, which can stand the test of time.

This is the European way. This has been our compass in these five years of work.

Multilateral solutions for non-proliferation and disarmament.

Multilateralism for peace and security.

In a changing world, this is still the best way forward. The only way towards a more peaceful and secure future.

Thank you.

## Opening Address of the Committee on International Security and Arms Control of the US National Academy of Sciences

Raymond Jeanloz
US National Academy of Sciences, Washington, DC, USA
e-mail: jeanloz@berkeley.edu

It is a great pleasure to join my distinguished colleagues in welcoming you to the Twenty-first Amaldi Conference on International Cooperation for Enhancing Nuclear Safety, Security, Safeguards and Non-Proliferation.

I am especially pleased that the US National Academy of Sciences Committee on International Security and Arms Control has had the opportunity to collaborate with the Accademia Nazionale dei Lincei in organizing this important meeting. Our venue—within a Member State of the European Union and NATO, and with close proximity to the Holy See—offers new opportunities for dialogue between states. It is truly inspiring to see such leading experts in science and technology, as well as in policy and moral domains, come together to address some of the world's most daunting problems.

These are problems in which science and technology have played a central role, and through which we hope that science and technology can help to identify fundamental solutions. Indeed, we continue to see the rapid development of technologies that promise great advances for human well being, but that also bring enormous challenges to the security and sustainability of modern societies. From climate change and environmental challenges, to the uncertain risks of bio-technology and threats in cyber and space domains, we see the potential for chaos and catastrophe associated with our most sophisticated human activities.

This is no less the case with the topic of the present conference: the nuclear threat. All the more so, as the nuclear domain includes the most physically powerful technologies developed to date by our species.

When I refer to science and technology providing solutions, I mean more than the invention of new technologies to help control those that already exist. Perhaps more significantly, I also mean applying the approaches used in science and technology, approaches that depend on communication; on collaboration; and on objective analysis leading to replicable results. In short, it is our intent for the scientific community to help civil society make the right decisions in containing and controlling technology, so that it best serves our mutual and collective benefit.

As an example of such approaches, I briefly describe the work of the Committee on International Security and Arms Control. Within the US Academy, the Committee works to address the most daunting problems in international security, including control of nuclear, biological, cyber and space technologies; and on countering terrorism and the malicious proliferation of technologies. As with the rest of our Academy, we focus on independent analysis based on reliable evidence, whether or not the results are comfortable to us or to our government.

One of our main activities is to use the global network of communication and collaboration among scientific researchers to establish new channels of communication between nations. In particular, we initiate discussions on security topics that are too difficult for direct communication between governments. The topics may be scientifically demanding, or politically sensitive for one side or the other, but the objective is to start with a technical focus in order to create conditions for communication—and ultimately dialogue—between nations.

The nature of this approach requires that we work quietly, with the least public attention possible, as discussions are initiated, and mutual trust can be established. I should clarify that although we are independent, our activities are scrutinized by our Academy and discussed with our government in order to ensure that our work is appropriate, sound and helpful. One measure of our success is then the extent to which our discussions are taken over into direct government-to-government communications.

We have longstanding experience in developing such channels of communication, including decades' worth of quiet dialogues with several partners. Nevertheless, it is sometimes necessary to discuss more publicly the critical matters that face humanity in international security. Recent developments around the world, including modernization of nuclear arsenals; the evolution, if not erosion, of arms control regimes; the increased recognition of enormous humanitarian and environmental consequences of nuclear war; and many more reasons impel us all to bring relevant scientific knowledge to the world at large, and this is the point of the present conference.

I therefore want to end my remarks so that we can proceed with our important agenda. There is much work to be done; and it is time for us to move forward with our discussions.

## Opening Address of the International Security and Arms Control Working Group of the Accademia Nazionale dei Lincei

Luciano Maiani
Accademia Nazionale dei Lincei, Rome, Italy
e-mail: luciano.maiani@cern.ch

It is a great honour and pleasure to open the XXI Amaldi Conference on International Cooperation for Enhancing Nuclear Safety, Security, Safeguards, and Non-Proliferation, organised jointly by the Accademia Nazionale dei Lincei and the US National Academy of Sciences, with the support of Ministero degli Affari Esteri, Consiglio Nazionale delle Ricerche and Istituto nazionale di Fisica Nucleare.

We gratefully acknowledge the patronage of the Conference by the President of the Italian Republic.

*A few dates*—The Edoardo Amaldi Conferences have been established at the end of the Eighties from the efforts of distinguished scientist, with a vast participation of the Scientific Community, to provide accurate and unbiased information to their Governments on the themes of Disarmament and Arm Control.

1980. The US National Academy of Sciences establishes CISAC (Committee on International Security and Armament Control), to maintain bilateral contacts with an analogous group at the Soviet Academy of Science. Among CISAC components Wolfgang Panofsky, eminent physicist, founder and first director of the Stanford Linear Accelerator Center. Panofsky Co-Chaired CISAC from 1985 to 1993, together with E. P. Velikov. The CISAC meeting on International Security and Armament Control was soon extended beyond the limitation of a direct link between the USA and the USSR. About ten scientists from European countries participated. The possibility of establishing in Europe a group of scientists with a role analogous to that of CISAC was discussed.

1987. Edoardo Amaldi sets up SICA (a working group on International Security and Arms Control), at Accademia dei Lincei. A first informal SICA meeting was held in Rome at Lincei on 23–25 June 1988: Workshop on International Security and Disarmament: The Role of the Scientific Academies. While preparing the third Meeting, Edoardo Amaldi unexpectedly dies. He was then President of Accademia Nazionale dei Lincei.Participants of the 1990 meeting decided to dedicate future meetings to the memory of Edoardo Amaldi, hence the name Edoardo Amaldi Conferences.

1991–2011. Edoardo Amaldi Conferences have been regularly held at Lincei and elsewhere in Europe.

In 2015 and 2017. With the support of Ministero degli Affari Esteri, the present format of the Edoardo Amaldi Conferences was adopted, with important participation from new countries in the Middle East and Asia (China, Egypt, India, Isreal, Iran, Japan, Pakistan).

*Back to our origin*—2019 SICA (Accademia dei Lincei) and CISAC (US National Academy of Sciences) have Co-organised the 21st edition.

From the next year, the Lecture on Security and Disarmament, held in 2016 and 2018 under the name of Edoardo Amaldi Lecture, will transform into the Amaldi-Panofsky Lectures and will be organised by the US NAS in Washington, DC.

*Towards a Nuclear-Weapon-Free World*—The Scientific Community has actively participated in the effort towards a Nuclear Weapon-free World, since the very aftermath of Iroshima and Nagasaki.

Non-Governmental Organizations, with the Pugwash Conference Organization, the International Physicians for the Prevention of a Nuclear War (IPPN) and others have greatly contributed to raise in the public opinion the awareness that employing nuclear weapons is absurd under any possible circumstance.

Multilateral organizations, the United Nations, the International Atomic Energy Agency, the Comprehensive Nuclear-Test-Ban Treaty Organization and others have provided impartial, objective, authoritative reporting of the behaviour of individual states otherwise impossible to provide to the international public opinion.

These are the pillars under which considerable progress on Security and Arm Control has taken place over the last decades, starting from the Non-Proliferation Treaty of 1970.

The efforts have been recognized by four Nobel Peace Prizes: in 1985 (given to the International Physicians for the Prevention of Nuclear War), 1995 (to Joseph Rotblat and to the Pugwash Conferences on Science and World Affairs), 2005 (to Mohamed Elbaradei and to the International Atomic Energy Agency) and in 2017 (to the International Campaign to Abolish Nuclear Weapons—ICAN).

*The XXI Amaldi Conference*—The past five years have seen a dramatic escalation in the danger of nuclear conflicts and many positive steps towards disarmament and arms control are in danger. Resuming the dialogue among different blocks, ideologies and cultures is badly needed.

The Twenty-first Edoardo Amaldi Conference aims to provide a forum where eminent scientists, diplomats and policy makers will be able to compare national perspectives and international collaborations, while discussing how "Science beyond Boundaries" will enhance nuclear non-proliferation policies.

We wish you all a fruitful and interesting participation.

Before concluding, I would like to express our sincere thanks to:

- Marcia Mc Nutt and Giorgio Parisi, Presidents of US National Academy of Sciences and of Accademia Nazionale dei Lincei, for their continuous encouragement;
- Ministero Affari Esteri, CNR, INFN for support;
- The Scientific Board: Raymond Jeanloz, Co-chair, Wolfango Plastino, Scientific Secretary, Marvin Adams, Francesco Calogero, Steve Fetter, Micah Lowenthal, Alberto Quadrio Curzio, Carlo Schaerf and Edoardo Vesentini, Members, for their valuable support;
- RAI TV for efficiently covering our event.

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# Contributors


**Marvin Adams** Texas A&M University System, College Station, TX, USA

**Massimo Aparo** International Atomic Energy Agency, Vienna, Austria

**Barry Barish** California Institute of Technology, Riverside, CA, USA

**Francesco Calogero** Sapienza University of Rome, Rome, Italy

**Sebastiano Cardi** Ministry of Foreign Affairs and International Cooperation, Rome, Italy

**Paolo Cotta-Ramusino** Pugwash Conferences on Science and World Affairs, Rome, Italy

**C. S. Eliot Kang** US Department of State, Washington, DC, USA

**Steve Fetter** University of Maryland, College Park, MD, USA

**Paul Richard Gallagher** Holy See's Secretariat of State, Vatican City, Holy See

**Kazem Gharib Abadi** Ministry of Foreign Affairs, Teheran, Islamic Republic of Iran

**Robin Grimes** Imperial College London, London, UK

**Rafael Grossi** Ministry of Foreign Affairs, Buenos Aires, Argentina

**Jill Hruby** Nuclear Threat Initiative, Washington, DC, USA

**Li Hua** China Academy of Engineering Physics, Beijing, People's Republic of China

**Raymond Jeanloz** United States National Academy of Sciences, Washington, DC, USA

**Caroline Jorant** Strategie de Developpement et Reglementations Internationales Consulting, Paris, France

**Vladimir Leontiev** Minsitry of Foreing Affairs, Moscow, Russian Federation

**Micah Lowenthal** National Academy of Sciences, Washington, DC, USA

**Luciano Maiani** Accademia Nazionale dei Lincei, Rome, Italy

**Antonio Missiroli** North Atlantic Threaty Organization, Brussels, Belgium

**Muhammad Naeem** Pakistan Atomic Energy Commission, Islamabad, Pakistan

**David Nusbaum** Israel Atomic Energy Commission, Tel Aviv, Israel

**Sergio Orlandi** International Thermonuclear Experimental Reactor, Saint-Paul-lez-Durance, France

**Young-Ho Park** Korea Institute for National Unification, Seoul, Republic of Korea

**Alberto Quadrio Curzio** Accademia Nazionale dei Lincei, Rome, Italy

**Alicia Sanders-Zakre** International Campaign to Abolish Nuclear Weapons, Geneva, Switzerland

**Carlo Schaerf** Tor Vergata University, Rome, Italy

**Tammy Taylor** Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria

**Tibor Tóth** Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria

# Part I
# New and Evolving Voices in Arms Control and Disarmament

# Chapter 1
# Introduction

**Alberto Quadrio Curzio**

As Chairman of the panel, "New and evolving voices in arms control and disarmament", I take the opportunity to start with an evaluation as president emeritus of Lincei and member of the board of Amaldi Conferences.

In fact, this initiative has many aspects of method that fulfill the aims of a National Academy like Lincei. I refer mainly to the role of sciences for policies[1] in fields that are relevant for human development. In the case of Amaldi Conferences, sciences are connected both to policies and to politics in the worldwide scenario under the umbrella of mutual understanding that this initiative has built up since 1988.

The panel of my chairmanship implies many of these aspects that can be classified, at least, in the two broad categories of institutional and economic issues while heavily focusing on the core topic of international security.

*Security and Complexity*—The concept of security, in its very general meaning, points to the preservation of a condition of safeness, both for states and individuals but in a more precise meaning must be considered in the context of a global growing condition of complexity and economic interdependence.

The concept of complexity in contemporary world reveals to be of great interest when it is associated with the issue of nuclear disarmament, which implies now an interplay of institutional and political, economic and social factors.

One way to show this complexity of interplays is to start with the problem of climate change which is in these days one of the most known and discussed. To many it might appear far from that on nuclear disarmament and this is exactly the reason on which we base our reasoning to demonstrate the connections.

To date, the debate around climate change is framed in terms of adaptation. If adaptive actions to climate change are to be taken, there could be a point beyond

[1] See also Accademia Nazionale dei Lincei, "*G7 Science Academies Meeting 2017*", Bardi Edizioni, Rome 2017.

A. Quadrio Curzio (✉)
Accademia Nazionale dei Lincei, Rome, Italy
e-mail: quadriocurzio@lincei.it





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which adaptation could be more cost sensitive than nuclear deterrent. This is the case of the would-be water scarcity in the Himalayan region, related to the melting of the Himalaya's glaciers, that constitute the major source of fresh water for, at least, India, Pakistan and the western regions of China. These three countries are all nuclear powers and, in the worst-case scenario, their nuclear deterrent could turn into the most viable option to exert political and military pressure over their neighbors in order to secure their fresh water supplies. This example, extensively cited in international fora to address the theme of climate change, helps us in understanding many of the facts and findings exposed by the contributors to this panel.

*Bilateralism and Multilateralism*—The institutional and economic aspects of nuclear disarmament are strictly intertwined to the extent that the institutional framework of disarmament initiatives must always take in consideration the economic landscape in which such disarmament should take place.

Looking to the past we must say that most of the existing nuclear arms control instruments reflect the cold-war concerns towards nuclear arms reduction and, in general, the U.S.–Russia competition for nuclear supremacy. Although a reduction in both the U.S. and Russia's nuclear arsenal is highly desirable, today most of the challenges arise from regional instability and nuclear proliferation by countries tempted by regional hegemonic 'adventures'.

Looking to the present and to the future the scenario changes. While maintaining a stronghold on existing bilateral disarmament initiatives, like the START, the INF and the Russian-U.S. arms control treaties, new emphasis should be put on existing global and multilateral nuclear disarmament initiatives, like the EU's and UN's. A particular stress is to be put on this point as multilateralism is the most powerful tool to achieve peace and development and is as well the issue-area in which Europe plays an important role. I would say that this role is fundamental, given the rising worldwide tendency towards neo-protectionism and neo-confrontation.[2]

The EU non-proliferation and disarmament consortium, as we all know, embodies the European Union's commitment to nuclear disarmament. The consortium is overtly devoted to make its contribution to nuclear disarmament worldwide, also at the legal level through a resolution of the European Parliament (res. 2016/2936).

United Europe has been built on peace, that is also one of its fundamental values as it is clearly stated in the preamble of the Treaty of Rome (1957):

> […] *Intending* to confirm the solidarity which binds Europe and the overseas countries and desiring to ensure the development of their prosperity, in accordance with the principles of the Charter of the United Nations,
>
> *Resolved* by thus pooling their resources to preserve and strengthen peace and liberty, and calling upon the other peoples of Europe who share their ideal to join in their efforts,
>
> *Determined* to promote the development of the highest possible level of knowledge for their peoples through a wide access to education and through its continuous updating […]

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[2]On these topics, see also: Alberto Quadrio Curzio, "Europa e profili di sviluppo", Accademia Nazionale dei Lincei, Relazione Conclusiva dell'Anno Accademico 2018-2019, Roma 20 Giugno 2019: https://www.lincei.it/sites/default/files/A_QuadrioCurzio_Europa_e_profili_di_sviluppo2019_06_20.pdf; and Alberto Quadrio Curzio, "Europa: il Futuro", Federazione Nazionale dei Cavalieri del Lavoro, Napoli 28 Settembre 2019.

Extremely clear on these principles is article 11 of the Italian Constitution, which states:

> Italy rejects war as an instrument of aggression against the freedom of other peoples and as a means for the settlement of international disputes. Italy agrees, on conditions of equality with other States, to the limitations of sovereignty that may be necessary to a world order ensuring peace and justice among the Nations. Italy promotes and encourages international organisations furthering such ends.

The United Nation multilateral initiative, as we all know, is constituted by the new agenda 'Securing Our Common Future', launched by the Secretary General António Guterres, in May. In December, the UN General Assembly First Committee adopted a resolution calling for the UN Secretary General to convene a conference in 2019 on creating a weapons of mass destruction free zone in the Middle East and every year thereafter until a zone is achieved.[3]

*Nuclear disarmament: the inadequate transparency*—Moreover, when addressing the problem of nuclear disarmament, two key issues deserve great attention: transparency and cost.

As for January 2019, the estimation for the total amount of nuclear weapons stockpiles around the world was of 13,865, distributed among 9 countries. The United States and Russia hold the 90% of the world total with respectively 6185 (USA) and 6500 (RUS), followed by France (300), China (290), the UK (200), Pakistan (150–160), India (130–140), Israel (80–90) and North Korea (20–30).

All these estimations are based on analytically based researches of independent bodies, like SIPRI,[4] according to the information disclosed by certain States. To this respect, attitudes vary significantly. Among the most transparent States, there are the United States and the UK, followed by France. These three States have disclosed reliable information about the status of their nuclear arsenals and the planned military spending in nuclear weapons (be it maintenance or renewal). Other States, like China, India and Pakistan, make no secret of their nuclear status, but disclose no information about the status of their arsenals or their planned military spending in that area. Finally, a longstanding domestic political tradition put Israel on the list of the total non-disclosure policy.

The Russian Federation follows a particular policy of public non-disclosure. The Russian government prefers instead to share the information with the U.S. government, in the framework of the New Start treaty negotiations.

Given this picture of the international reality, what can be said is that even if nuclear stockpiles followed a declining path across the last decades, the issue of nuclear disarmament keeps being obstructed by the lack of transparency by some of the existing nuclear powers. The main point is that, even if the total number of nuclear warheads declines, nuclear capabilities do not. The lack of transparency in military spending for nuclear programmes make it difficult to assess whether or not

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[3]Res. A/C.1/73/L.1 (https://undocs.org/A/C.1/73/L.1). Israel, Micronesia and the United States voted against the resolution and 71 countries abstained.

[4]*SIPRI Yearbook 2019. Armaments, Disarmament and International Security*, pp.10–11 https://www.sipri.org/sites/default/files/2019-08/yb19_summary_eng_1.pdf.

governments invest money to increase the efficiency of smaller arsenals. This is a great challenge for nuclear disarmament and international peace.

This opens the issues of controls and sanctions, which will be dealt in the contribution of Tibor Tóth—Executive Secretary Emeritus CTBTO.

*Nuclear desarmament and military spending*—In 2018, the world total military spending has been estimated to be \$1.8 trillion in 2018, accounting for 2.1% of world gross domestic product (GDP) or \$239 per person. For the first time in history, the 2018 represented the highest point of global military spending. According to SIPRI 2019 yearbook data,[5] the five biggest spenders in 2018 were the USA, China, Saudi Arabia, India and France, which together accounted for 60% of global military spending. The USA increased its military spending for the first time in seven years to reach \$649 billion in 2018. Spending by the USA accounted for 36% of world military spending and was 2.6 times more than the next highest spender, China. The rise in U.S. military spending can be attributed to two factors: a 2.4% increase in the salaries of military personnel; and the implementation of large and costly conventional and nuclear arms acquisition programmes. China allocated an estimated \$250 billion to its military in 2018. This represented a 5.0% increase compared with 2017 and an 83% increase since 2009. China's military spending is roughly linked to the country's economic growth, which slowed in 2018 to the lowest level in 28 years. Slower growth in military spending can therefore be expected in the coming years.

*Some final remarks: Peace and Sustainable development goals*—To date, disarmement is included only implicitly and not explicitly in the Sustainable Development Goals (SDGs). The disarmament issue could be desumed from SDGs 16.1 and 16.4. According to the SDG 16.1, the aim must be that of "*Significantly reduce all forms of violence and related death rates everywhere*", while the SDG 16.4 says that "*By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime*". Another source from which one can desume a committment to disarmament can be found in the SDGs 3 (Good health and well-being), 4 (Quality education) and 8 (Decent Work and economic growth).

Besides the explicit reference of SDGs 16.1 and 16.4 to violence, arms trafficking and financial related issues, the linking point of SDGs 3, 4 and 8 to disarmament is represented by the different use of financial resources, from nuclear arms development towards social, sanitary and educational purposes.

To have an idea of the volume of the financial resources devoted to nuclear programmes development and of the possible different uses that public authorities could do of these resources, I will give you two examples.

The first one concerns the costs of the British 'Trident' nuclear programme. Every year, it costs to british taxpayers around £ 2bn and the british government has planned a total expense in nuclear programme's related activities a total amount of £ 100bn. At the same time, there are many studies pointing to the underfinancing of the National Health System (NHS), which is quantified in a gap of £ 2bn per year.

[5] *SIPRI Yearbook 2019. Armaments, Disarmament and International Security*, pp. 6–7 https://www.sipri.org/sites/default/files/2019-08/yb19_summary_eng_1.pdf.

Just to have an idea, the necessary investment to meet the requirements of SDG 9/6—Basic infrastructure: roads, rail and ports; power stations; water and sanitation; SDG 2—food security: agriculture and rural development; SDG 12/13—climate change mitigation and adaptation; SDG 3–5: health and education, should be comprised between 4 and 7 trillion U.S. dollars per year globally (World Investment Report 2014, UNCTAD).

Obviously the goal of disarmament, at least at the nuclear level, is both ambitious and difficult to realize. As it happens in every field of human activity, uncertainty and lack of complete informations could discourage international actors to take desarmament initiatives. To this respect, as Robin Grimes—Rs And Mod, United Kingdom, in this session tells us, interests and needs are to be taken in consideration also in the institutional design process of desarmement initiatives.

I like to conclude mentioning the speech of Amb. Cardi who express the official position of the Italian Institution. He is very clear on the possibility of factoring in the element of multilateralism. In a condition of uncertainty, incomplete information and cost-benefit approach to nuclear disarmament, the multilateral institutional design is the only viable option in taking new initiatives and boosting existing ones in the field of international nuclear security.

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# Chapter 2
# Message to the Participants of the XXI Edoardo Amaldi Conference

**Paul Richard Gallagher**

Your Excellencies, distinguished Panelists, dear Ladies and Gentlemen,

It is a pleasure to address you with a brief message at the XXI Edoardo Amaldi Conference on International Cooperation for Enhancing Nuclear Safety, Security, Safeguards and Non-Proliferation.

Today's meeting is very pertinent, given the difficulties that we are unfortunately witnessing in the field of arms control and, in particular, nuclear weapons disarmament and non-proliferation.

As mentioned recently by His Eminence Card. Pietro Parolin, the Holy See's Secretary of State, at the General Assembly High-Level Plenary Meeting to commemorate and promote the International Day for the Total Elimination of Nuclear Weapons (New York, 26 September 2019), "the lapse of the Intermediate—Range Nuclear Forces Treaty, the failure to achieve entry into force of the Comprehensive Nuclear-Test-Ban Treaty, the inability of the Conference on Disarmament even to begin negotiations on a ban on the production of fissile material for nuclear weapons, the so-called "modernization" of nuclear weapons and delivery systems, and the instabilities at play in the implementation of the Joint Comprehensive Program of Action [...] are worrying signs of an erosion of multilateralism and of the ruled-based order [...] One might be tempted to lose hope in face of the setbacks, the impasse or the very slow progress in the disarmament agenda, in particular in the area of nuclear disarmament. However, perseverance and determination should characterize our common efforts to move toward the elimination of nuclear weapons. We must make every effort to avoid dismantling the international architecture of arms control, especially in the field of weapons of mass destruction" .

The Holy See is totally committed in this effort. This is demonstrated by the fact that it is Party to the main multilateral Treaties concerning nuclear weapons:

P. R. Gallagher (✉)
Holy See's Secretariat of State, Vatican City, Holy See
e-mail: rapportistati@sds.va



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the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and the Treaty on the Prohibition of Nuclear Weapons. Each is a component of the international regime of nuclear disarmament and non-proliferation, which also includes the IAEA Safeguards Agreements and related Additional Protocols, the Agreements for nuclear-weapons-free zones, as well as various other bilateral agreements. All of them play a complementary role in the difficult path to achieve the long-term and complex goal of a nuclear weapons free world, desired by the whole international community.

The common goal of a nuclear free world was underlined by Pope Francis at a symposium held at the Vatican in November 2017, where he emphasized that nuclear weapons exist "in the service of a mentality of fear that affects not only the parties in conflict but the entire human race. International relations cannot be held captive to military force, mutual intimidation, and the parading of stockpiles of arms. Weapons of mass destruction, particularly nuclear weapons, create nothing but a false sense of security. They cannot constitute the basis for peaceful coexistence between members of the human family, which must rather be inspired by an ethics of solidarity".

Your Excellencies,

At the recent XI Conference to facilitate the entry into force of the Comprehensive Nuclear-Test-Ban Treaty (New York, 25 September 2019), Card Parolin said that "the norms embodied in the UN Charter, international humanitarian law, disarmament and arms control instruments, and other elements of international law represent an indispensable commitment to cooperative security and a juridical embodiment of this global ethic of responsibility that is now sorely needed".

The Holy See has indeed often reaffirmed in international forums on disarmament the importance of concretely promoting the culture of life and peace, founded on the dignity of the human being and on the primacy of law, through a multilateralism based on dialogue and the responsible, honest cooperation of all members of the community of nations. These are indispensable elements for the construction of real and lasting trust, a fundamental element for guaranteeing international security and peace.

We must work tirelessly to restore any possibility of dialogue and to fight the trust-deficits, which unfortunately characterize the current environment around nuclear disarmament and non-proliferation, especially since strengthening dialogue and rebuilding trust to be one of the major aims of this thought-provoking Conference.

With this in mind, I would like to recall what was said by Pope Francis in His Message to the United Nations Conference to Negotiate a Legally Binding Instrument to Prohibit Nuclear Weapons, Leading Towards Their Total Elimination on 27 March 2017: "Growing interdependence and globalization mean that any response to the threat of nuclear weapons should be collective and concerted, based on mutual trust. This trust can be built only through dialogue that is truly directed to the common good and not to the protection of veiled or particular interests; such dialogue, as far as possible, should include all: nuclear states, countries which do not possess nuclear weapons, the military and private sectors, religious communities, civil societies, and international organizations. And in this endeavour we must avoid those forms of mutual recrimination and polarization which hinder dialogue rather than encourage it. Humanity has the ability to work together in building up our common home; we have the freedom, intelligence and capacity to lead and direct technology, to place limits on our power, and to put all this at the service of another type of progress: one that is more human, social and integral".

Thank you.

# Chapter 3
# The Risks of Nuclear Proliferation: Addressing the Challenge

**Sebastiano Cardi**

Chairperson, Excellencies, Ladies and Gentlemen,

I am very pleased to intervene at this panel of the "Amaldi Conference" dedicated to "New and evolving voices in arms control and disarmament" and chaired by the President emeritus of the Accademia dei Lincei, Prof. Alberto Quadrio Curzio. I am particularly glad to be here today with an eminent scientific expert from the Ministry of Defense of the United Kingdom, Prof. Robin Grimes, and with the Executive Secretary Emeritus of the CTBTO, Ambassador Tibor Tóth.

This year, the "Amaldi Conference" falls within the preparatory process towards the 2020 Review Conference of the Non Proliferation Treaty (NPT). As in previous interventions, I would like to emphasize the central role of the Treaty in underpinning the global nuclear non proliferation regime. The NPT three pillars structure is well balanced and mutually reinforcing. Let me also underline that (i) nuclear disarmament, (ii) non-proliferation and (iii) peaceful uses of nuclear energy are definitely of equal importance.

In view of the 2020 Conference, Italy believes that the Action Plan agreed in 2010 has to be implemented in a full, balanced and comprehensive manner. What can still be done in the framework of the Action Plan and what additional measures may be undertaken will have to be part of the reflection of the Review Conference.

The proliferation of nuclear weapons represents today a major threat to international security. The existence of programmes to develop such weapons, the action of criminal proliferation networks, the difficulty of securing sensitive materials and the risk that non-state actors and terrorist groups might get access to them remain major challenges to cope with.

In this respect, the International Atomic Energy Agency (IAEA) system of safeguards—multilateral, impartial, professional and responsible as it is—represents a fundamental guarantee for our common security. In all relevant international fora,

S. Cardi (✉)
Ministry of Foreign Affairs and International Cooperation, Rome, Italy
e-mail: sebastiano.cardi@esteri.it



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Italy promotes the universalization of the IAEA Comprehensive Safeguards Agreements together with an Additional Protocol as the international verification standard. Italy systematically calls on all States who have not yet done so to sign and bring into force the Additional Protocol and, where relevant, adopt the modified Small Quantities Protocol.

Let me indeed recall that the Model Additional Protocol significantly increases IAEA's ability to verify the peaceful use of all nuclear material in States with comprehensive safeguards agreements.

This draws me to evaluate with you the current status of the Joint Comprehensive Plan of Action, under which Iran has committed intern alia to provisionally apply the Additional Protocol in relation to the verification of its nuclear-related obligations.

The JCPOA is a key element of the global non-proliferation architecture and an achievement of multilateral diplomacy endorsed by UNSCR 2231. I am therefore deeply concerned by the severe difficulties, to which it is nowadays exposed. Its implementation remains crucial for regional and international security. Iran should return to full compliance without delay.

Let me also stress that Italy is ready to support all initiatives aimed at restoring the JCPoA's integrity and de-escalating the present tensions in the region. In this regard, I am personally involved in a potentially helpful exercise of dialogue in relation to the situation in Yemen, whereby France, Germany, Italy and United Kingdom seat together with Iran to address possible solutions for the conflict.

Let me also recall the long-standing support by Italy to the establishment of a zone free of nuclear and all other weapons of mass destruction and their delivery systems in the Middle East. We continue to believe that the zone should be established on the basis of arrangements freely arrived at among all the States of the concerned region. We are ready to engage with all relevant players to achieve that.

In terms of challenges to the global non proliferation regime, North Korea's nuclear and ballistic missile programmes remain an issue of serious concern. We positively consider the dialogue launched by the US Administration with the leadership of North Korea. However, we strongly believe that the current sanction regime should remain in place as long as Pyongyang does not undertake concrete steps towards a complete, verifiable and irreversible denuclearization. Among these steps, we of course envisage the return to the NPT, the implementation of the IAEA Comprehensive Safeguards Agreements together with an Additional Protocol, and the signature and ratification of the CTBT.

The global non proliferation regime is under pressure also in relation to the threat posed by the proliferation of weapons of mass destruction and their means of delivery to—and through—non-state actors.

This is why Italy strongly supports the full and universal implementation of UNSCR 1540 (2004) and its follow-on Resolutions, as well as the role of the 1540 Committee in facilitating technical assistance for appropriate domestic controls over WMD related materials in order to prevent their illicit trafficking.

Italy is also considerably engaged in relevant international non-proliferation partnerships, notably the Proliferation Security Initiative (PSI) and its Mediterranean Initiative. We hosted a table top exercise in Rome in 2016 and organized a livex naval exercise at the port of Catania in 2018. Both exercises gathered many high level officials from PSI partners to share expertise, best practices and resources to build robust capacities among partners for combating illegal trafficking of dual use items, dismantling smuggling networks and conducting interdiction operations under an established and functioning cooperative framework in accordance with international law. In the light of this strong commitment under the PSI framework, Italy has accepted to take over the Presidency of the PSI Operational Expert Group for 2020 (this is the coordination core group of the Initiative).

Italy remains committed to the achievement of a better international nuclear security environment. Ensuring the highest levels of nuclear security is a shared interest of the international community. We strongly support the central role of the IAEA in the global nuclear security framework and we encourage all States to fulfil their nuclear security responsibilities.

Italy has ratified the Amendment to the Convention on the Physical Protection of Nuclear Material (CPPNM) and the International Convention for the Suppression of Acts of Nuclear Terrorism (ICSANT). We actively participate in the activities of the Nuclear Security Contact Group (NSCG), in the Global Initiative to Combat Nuclear Terrorism (GICNT) and in other relevant international and European initiatives.

As a further demonstration of our commitment to promote a nuclear security culture and capacity building worldwide, Italy has been funding over the last years the International School on Nuclear Security, jointly run by the IAEA and the International Centre for Theoretical Physics (ICTP) in Trieste. The School is highly valued by developing and emerging countries, for its contribution to the development of a cadre of professionals in the national framework governing nuclear safety and security.

Against this backdrop, we look forward to the next International Conference on Nuclear Security (ICONS), which will take place in February 2020, as an important opportunity to build on experiences and achievements and devise future directions, approaches and priorities for nuclear security.

Let me finally recall the need to recognize the changing nature of the existing threat, react, adapt and step up our efforts for reinforcing the global non-proliferation regime. Risks may indeed arise from a variety of sources: states aspiring to possess nuclear weapons; non-state actors in search of "dirty bombs"; poor national legislation in place to prevent illicit trafficking of materials and dismantle proliferation networks, as well as from mismanagement and misuse of rapid development of science and technology.

I would like therefore to conclude this intervention by highlighting the importance of further analysis and research in the field of non-proliferation. In this respect, the traditional bi-annual gathering of the "Amaldi Conference" is an excellent opportunity of debate and analysis among international high-level experts and officials.

Let me also recall the EU Consortium of non proliferation and disarmament think tanks, which is very well placed for such endeavour of research. I am particularly pleased that as of 2018 the Rome-based International Affairs Institute is part of the Consortium and is the leading think tank for the international non-proliferation conference, which many of you annually attend (this year is foreseen for December in Brussels).

Thank you for your attention.

# Chapter 4
# Preferred Courses of Action for Security as Nuclear Arms Control Changes in the 2020s

**Tibor Tóth**

Before we embark upon projecting preferred courses of action for security into the 2020s as it is prescribed by the title of this contribution it might be timely to undertake a travel back into the recent past and recall how each of us had perceived ten years ago the prospects of strengthening international security for the 2010s.

For me it was a period of optimistic expectations. As the Executive Secretary at that time of the Comprehensive Nuclear Test-Ban Treaty Organization's Preparatory Commission, I anticipated a series of concrete steps strengthening international security in the years and decade to come. My expectations and the expectations of many other practitioners of nuclear arms control were fueled by the upsurge of interest in nuclear arms control and disarmament as witnessed among others by the 2007 proposals of the 'Four Horsemen of the Nuclear Apocalypse', the 2009 Prague speech of president Obama and an emerging nuclear abolition movement.

A few of the measures projected through these and other initiatives have been delivered like the New Start Treaty or the Treaty on the Prohibition of Nuclear Weapons. Many others have not. As a particular disappointment not just for me, but for many others as well, was that no significant breakthrough happened on the entry into force of the CTBT. Notwithstanding the well-founded expectations a decade ago, the 2010s have not gone down into history as a period of bringing about the necessary number of *cooperative* security measures embodied in arms control, disarmament and other soft diplomacy tools versus the flare up of *competitive* security, that is military competition and coercive measures fueled by geopolitical drivers.

The disappointing track record of the decade behind us begs for the question why so few cooperative security measures were put in place? Were those packages of cooperative security promoted merely as part of expectation management? Or was the aggregate sum of the projected measures overly ambitious as president Obama

T. Tóth (✉)
Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
e-mail: ecubator2tb@gmail.com



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himself implied in his Prague speech? Or was it just the wrong time for the right measures?

We have to address those questions *now* instead of a belated 'what went wrong' soul-searching again in ten years time. Or what is worst, we should not embark again upon the ritual of pre-NPT review conference goal setting without understanding why it was not feasible to deliver during the 2010s those cooperative measures so many had considered not just essential, but feasible.

Obviously, in the years to come we will not give up on mitigating international security challenges, as they represent one of the wickedest of the 'wicked problems' eclipsed in their severity only by climate change and global pandemics. At the same time while doing that we should build our *mitigation* efforts on *measuring* and *modelling* of why previous mitigation efforts went wrong and how to deploy future ones successfully. Grounding mitigation in measuring and modelling of both the challenge and the intervention would enable us to look beyond the contradictory trade-offs between cooperative security requirements and competitive security *Realpolitik*. Combining the three Ms might help to understand better the 'when' question: why cooperative security measures are feasible at certain points in time, but they fail at others?

In order to do all that we need a new *conceptual framework* as well. In a 2016 article[1] I sought to apply the conceptual models used to describe market trends to international security. In doing so, I illustrated the historically prevailing state of play in the quantitative and qualitative nuclear arms race as trend indexes in the ever-changing mix of competitive and cooperative means of pursuing security between states. Market-trends observation and terminology was applied to make the security trend comparisons more easily intelligible.[2]

Along the lines of that article a proposed new conceptual framework within which we undertake measuring, modelling and mitigation would require departures from prevailing cooperative security assumptions:

- We go beyond the NPT review conference-centric assessment of cooperative security requirements. Going even further, we step out of the boundaries of reiterating the prevailing lists of proposed cooperative security measures.
- We assume (though we do not condone), as a present system-of-systems reality, that the mix of cooperative and competitive security measures is not defined by cooperative security, but—the other way around—driven by competitive security.
- We postulate that competitive security itself seems to follow a cyclical pattern of booms and busts. In each post-bust cycle, security is increasingly left to 'self-regulating' market forces of more and more unconstrained competition.

[1]Conflict, cooperation, and the Comprehensive Nuclear-Test Ban Treaty: financial markets as a metaphor for cycles in global security [1].

[2]Terms like cycles of boom and bust; bubbles inflated and burst; market adjustment, crash, panic, crisis, recession and depression; bull and bear markets; secular (couple of decades) and primary (couple of years) timeframe.

- As a result of overinvestment in competitive security accompanied by counter-cyclical regulatory tools removed through unilateral of coordinated 'deregulation', eventually each cycle ends up with a security market "correction" or "crash".
- It is when the competitive bubble bursts and mainly in the aftermath of the ensuing *security* "panic" or "recession" that regulatory, cooperative security tools are belatedly embraced. Both the Limited Test-Ban Treaty (LTBT) of 1963 and the Comprehensive Nuclear-Test Ban Treaty (CTBT) of 1996 were put in place as global-security regulations primarily as a result of the bursting of a cyclical competitive-security bubble with near-fatal global consequences during the Cuban missile crisis in 1962 and in the INF crisis of the late 1970s and first half of the 1980s, respectively. In both instances, post-crash a multitude of multilateral and bilateral disarmament, arms-control and non-proliferation agreements were acknowledged as crucial regulatory tools in the wake of 'never again' collective soul-searching.
- We assume however, that after a while security balance is sought again through the 'invisible hand' of deterrence and competition forces. As soon as the new competitive boom picks up again cooperative-security arrangements are eroded, overshadowed and squeezed out by a new recurring cycle of competitive security.
- And last, but not least, we postulate the potential emergence of a 'super bubble': the present competitive security bull market that emerged from the mid-1990s is a long-term (secular) one and it coincides from the late 1990s with recurring crises in the financial, economic and social spheres.

The above conceptual framework is admittedly unconventional to prescribe preferred courses of action for security into the 2020s. It assumes that we can't define the security requirements of the decade in the narrow context of how nuclear arms control changes. Furthermore it suggests that even the unorthodox postulate of cooperative security being defined and driven by the boom and bust cycle dynamics of competitive security, is not sufficient to put our arms around the security requirements of the 2020s.

While addressing mitigation, security policy decision-makers and practitioners will have to monitor not just the cyclical dynamics of a two-decades long competitive security bull market and the need for regulatory counter-cyclical measures before the bubble bursts. They have to measure, model and mitigate an emerging super bubble: the spill-over and reinforcing dynamics of the prevailing *crises* in the financial, economic and social spheres intermingling with the critical build-up of a security bubble. Even in the darkest days of the Cuban missile crisis or the INF-crisis we had not collectively faced such a super bubble. It was in the 1890s and the 1920s such a cyclical convergence emerged in modern history. In both cases the super bubble did burst with unprecedented consequences.

In a world with still nearly twenty thousand warheads, two hundred thousand warheads worth of plutonium and uranium in military and civilian stocks, two hundred thousand tons of spent fuel scattered around hundreds of nuclear power plants all of us, be it decision-makers, practitioners or observers will have to embrace a new approach to security in the 2020s, both in concepts and in practice.

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# Chapter 5
# Interests and Changing Needs from Arms Control, Disarmament, and Non-proliferation for International Security

**Robin Grimes**

Perhaps, before I start my formal comments, I should mention one of the activities I am currently engaged on, particularly relevant to the topic before us.

I chair within the JCPOA framework both the Arak Working Groups and the Arak Technical Experts Groups. Thus, my job, in collaboration with colleagues from China, Russia, France, Germany and the EU Commission, is to help guide the Arak project forward. This is a heavy water moderated and heavy water cooled test reactor. The aim is to keep this reactor away from proliferative uses throughout its design, build and operation. I want to emphasise my personal commitment as well as that of the UK.

So, let me start the formal presentation with some general thoughts concerning the International Rules-Based System and Arms Control, including the role of science.

Without respect for and confidence in, some form of agreed international system of rules and behaviour we will not achieve international security. Change in the approach to the international-rule-based system therefore raises significant concerns.

Nevertheless, renewed emphasis on the international rules-based system is crucial as we need to create an environment reinforced by confidence. This can be supported by rules, transparency and verification, underpinned by evidence and assured processes.

Of course, every party engaged in an arms control process must be confident this activity will not allow a strategic competitor an advantage, or that another party is cheating.

It is critical that all states recognise and respect each other's need for security. Undermining another country's sense of security will only lead to instability. An Arms Control endeavour must be win-win or cheating will be incentivised. The same is true for disarmament.

R. Grimes (✉)
Imperial College London, London, UK
e-mail: r.grimes@imperial.ac.uk



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Establishing the common interest, and the possibility of reciprocation are crucial to restoring arms control and discouraging cheating.

To make progress we need: political will; conducive international conditions; and sufficient trust between parties. We therefore need to co-operate!

The broader relations between parties are crucial considerations. If relations remain bad, vulnerabilities could become a major source of danger and potential war.

The Economist quotes Lawrence Freedman as having argued that “Arms Control tends to follow politics—not lead it.” The challenge therefore—if you agree with the premise—is how we develop the political will and political confidence for arms control. Of course, part of that is to have the tools available to carry out the job at hand.

In any case, strategic stability is also our focus and objective rather than arms control alone. But then again, strategic stability is achieved through a combination of arms control, deterrence, non-proliferation and arms reduction measures. So to my mind the argument is somewhat circular.

We also need to consider whether Arms Control in the future should remain single domain, accounting only for nuclear weapons, or whether we need a cross-domain framework that takes into account weapons systems that impact strategic calculations—including new technologies deployed in space and cyber, but also missile defence systems. Looking only slightly further ahead, AI will have a considerable impact across all these.

In general technology developments proceed at pace and we too often play catch-up to understand their impact on strategic stability, let alone how to respond within an arms control context.

But the only way we can achieve confidence is through verification, including disarmament verification. There is an international need for increasing co-operation in Verification—whether for disarmament or arms control or any future treaty on fissile materials for nuclear weapons. The most promising area of co-operation is in disarmament verification. This demands co-operation on technology development, especially the application of new science and technology and joint deployment practices.

*Let me now turn to the specific issue of Verification*—Developing and agreeing effective measures for verifying nuclear disarmament will be vital for enabling the fulfilment of the goals of Article VI of the NPT. Nuclear Weapon States and Non-Nuclear Weapon States alike will need to have confidence that nuclear-armed states have dismantled all their warheads, and that this has been carried out in a way that makes us safer and does not inadvertently increase the risk of nuclear proliferation.

Beyond the dismantlement of individual warheads, we also need to understand what monitoring and verification procedures may be required across a state’s nuclear and defence sites to provide sufficient confidence that nuclear disarmament has taken place irreversibly.

These present significant technological as well as political challenges. And I think human behavioural science has an under-appreciated part of play in helping us think more clearly and broadly about the effectiveness of activities and in measuring their impact. It complements the basic science and engineering.

Throughout the development of these verification measures, the UK places great importance on involving Non-Nuclear Weapon States and maximising transparency, while upholding our non-proliferation and security commitments.

The UK has continued to play a leading role internationally in the development of nuclear disarmament verification. The UK-Norway Initiative (UKNI), which began in 2007, was the first ever such technical partnership between a Nuclear Weapon State and a Non-Nuclear Weapon State. In 2015, building on UKNI's work, the UK established the Quad Nuclear Verification Partnership with Norway, Sweden and the United States.

In 2017, the Quad undertook the first ever multilateral disarmament verification exercise at RAF Honington. Known as LETTERPRESS, the exercise was held at RAF Honington's former nuclear weapons storage facilities, adding additional realism to the verification activities.

LETTERPRESS provided the opportunity to practice techniques and procedures in a simulated real-world scenario and explored challenges associated with monitoring and verification of declarations, as might be required in future treaties. The exercise was held in strict conformity with the non-proliferation obligations of all participants. The Quad have produced a report for the 2019 NPT Preparatory Committee summarising our work to date and lessons learned.

I think you can see one way in which we begin to explore and learn more about the interplay of technology and behaviour.

The UK has played an active role in the International Partnership for Nuclear Disarmament Verification (IPNDV) since its foundation in 2015. The IPNDV is an initiative that brings together a wide range of countries to identify and solve the challenges associated with nuclear disarmament verification.

As our collaborations on verification have developed, a common theme has been the extent to which Non-Nuclear Weapon States have been able to play a near-complete role in the process, while upholding their non-proliferation obligations. This has been possible by viewing the challenge in terms of the verification of nuclear materials and explosives.

The UK is also in the second decade of an active bilateral partnership with the United States in monitoring and verification research. Our joint technical cooperation programme allows us to apply policy, technology and programme expertise to develop and evaluate targeted approaches for transparent reductions and monitoring of: nuclear warheads, fissile material and associated facilities, for potential disarmament and non-proliferation initiatives. Technical experts conduct activities and share information to explore and address essential and difficult monitoring and verification challenges, working to integrate potential approaches for arms control monitoring and transparency.

The UK believes sharing the results of verification initiatives such as the Quad and IPNDV are important for demonstrating transparency, as well as building understanding and capacity for nuclear disarmament verification worldwide.

In parallel to developing verification we need to ensure and assure the non-proliferation of nuclear know-how and materials. This is another key area where international co-operation is required—and an area where the UK has been working to enhance measures.

*A key part of this narrative is Non-Proliferation*—A fundamental corner-stone of global peace and security is our ability to maintain the effective functioning of the global nuclear non-proliferation regime, centred on the enforcement of nuclear safeguards by the IAEA. Without these checks on proliferation, peaceful use of nuclear technology would not be possible.

All countries utilising peaceful nuclear technologies have a duty to finalise safeguards agreements with the IAEA and meet their obligations. The UK is no exception and continues to meet its obligations as a Nuclear Weapons State and responsible user of nuclear energy.

The UK Voluntary Offer Safeguards Agreement with the IAEA and Euratom came into force in 1978. This allows for the application of safeguards on all sources or special fissionable material in facilities or parts of them, subject only to exclusions for reasons of national security. In order to ensure we continue to meet our obligations once Euratom arrangements no longer apply in the UK, we have agreed a new VOA and Additional Protocol with the IAEA, and our new safeguards arrangements are ready.

The UK supports the IAEA's continued efforts to strengthen the international safeguards system across the world, which is an integral part of the global non-proliferation regime within the framework of the NPT. One such element of our support to the IAEA is the UK Safeguards Support Programme (UKSP) which has provided practical assistance to support the strengthening of IAEA safeguards since 1981.

Currently our priorities are to provide training of IAEA inspectors, assistance to enhance the IAEA's safeguards IT infrastructure and participation in the Network of Analytical Laboratories (NWAL). Through NWAL, the UK supports non-proliferation by analysing environmental and bulk samples at the request of the IAEA.

I believe the academic community has a greater role to play here, especially in sharing emerging science across its community, thereby progressing international credibility. Nuclear forensics is an area for which this approach is being effective. At the University of Bristol this summer we initiated a series of international conferences on nuclear forensics, supported by the IAEA. This meeting reviewed the engineering and science behind new and existing techniques. We will hear more about science diplomacy later in the conference but I want just to emphasise the increasing role that academies can play, as evidenced by the conference.

*The last topic I will cover is the implementation of Safeguards*—The UK believes that a Comprehensive Safeguards Agreement plus an Additional Protocol is the universal verification standard as required by State Parties by the NPT.

The Additional Protocol is an important enhancement to safeguards implementation and the non-proliferation regime. It is a necessary change to ensure that safeguards are fit for the challenges of the twenty first century. Only the Additional Protocol can provide credible assurance of an absence of undeclared nuclear material and activities within a state.

The UK uses all opportunities to call upon all states that have not yet done so to bring an Additional Protocol into force as soon as possible.

The UK has also supported the evolution of safeguards implementation including through the State Level Concept (SLC). The UK judges that safeguards implementation by the IAEA must continue evolving to address new demands and new challenges incorporating the experience gained from past safeguards implementation and taking advantage of new techniques and technologies.

And the UK has reiterated these points on many occasions, including in the UK's official statements I have personally presented the IAEA General Conference.

The UK supports the IAEA's efforts to improve the efficiency of safeguards. This is vital because the quantities of materials, and number of facilities under safeguards, continues to grow.

*Let me finish with these remarks*—International co-operation is, of course, key to all of our approaches and endeavours—we need as many nations as possible on-board to make progress, both technologically and politically.

As peaceful nuclear technologies develop, and their use increases, particularly among developing economies, the effective, reliable and sustainable application of safeguards will grow ever more important. This is vital in view of the emergence of small and advanced modular reactors, mobile reactors and, nuclear co-generation as well as the increasing use of radioactive materials in medical, agricultural and scientific research applications.

Maintaining access to the many social, economic and scientific benefits of these technologies requires commitment to the supporting multi-lateral architecture, centred on the NPT and the IAEA, and compliance with obligations and responsibilities by the international community.

In today's uncertain international security environment, we potentially face new strategic technologies such as hypersonic and space-based weapons systems, cyber threats, and all augmented by the application of AI. It is clear there has never been a more important time to work together:

- to rebuild arms control in a manner that creates security and stability for all,
- to create the conditions for disarmament and,
- to implement and strengthen the treaties and measures required for non-proliferation.

Thank you for your attention.

# Part II
# Nuclear Weapons, Non-proliferation, and the Broader Security Environment

# Chapter 6
# Introduction

**Francesco Calogero**

Sophisticated deterrence theories have been proposed to justify the acquisition of nuclear weapons by countries; but they are demonstrably flawed and likely to lead to a catastrophic outcome; which has been avoided so far only thanks to the insubordination of individuals who did not follow the instructions mandated by such theories. The relevant military and political decision makers should try to escape from this dangerous situation. This is not easy; but the alternative is doom.

Escape before doom might become possible after the danger of the current situation of humankind due to the presence of nuclear weapons is more widely understood. But it is more likely that a sufficiently potent motive for drastic changes shall emerge only after a major nuclear-weapon catastrophe caused by a diligent implementation of the sequence of the actions carefully programmed to make nuclear deterrence work. All of us—and primarily all those of us having some specific competence or professional involvement in the development and operational management of nuclear weapons (their technologies, their operational rules, and the related domestic and international politics)—especially all those who do believe their activities related to nuclear weaponry help to promote the survival of their fellow citizens and of humankind—all ought to ponder these facts and cooperate in order to move humankind away from the brink.

*Si vis pacem, para bellum*. "If you want peace, prepare for war". This advice was probably rather sensible in many of the occasions in which it was uttered and followed throughout human history; but these were circumstances in which the primary goal was to avoid war if at all possible, but otherwise to win the war. Now every reasonable person understands that "a nuclear war cannot be won and must never be fought" (President Ronald Reagan, 1984 State of the Union Address). Hence, any "reasonable" version of nuclear deterrence must have as its primary goal the prevention of nuclear war: indeed, of any deliberate use of nuclear weapons.

F. Calogero (✉)
Sapienza University of Rome, Rome, Italy
e-mail: francesco.calogero@roma1.infn.it



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Attempts have been made to translate nuclear deterrence into a precise military doctrine eventually codified into a set of operational rules governing the eventual use *in bello* of nuclear weapons. This task has become extremely difficult after the development of Intercontinental Ballistic Missiles (ICBMs). This is not the place to enter into a sophisticated analysis of the subtleties that have therefore been invented by the theoreticians who have made their living by investigating—in various countries—the operational details of nuclear deterrence deliverable by ICBMs. Being myself a theoretical and mathematical physicist (rather than an experimental physicist), I should respect these intellectual exercises that have occupied the minds of quite clever individuals. But as a natural scientist I must also emphasize the necessity to confront theory with reality.

The theory of nuclear deterrence implies decisions about the development, manufacture and deployment of defensive and offensive nuclear weapons and, most importantly, the operational rules of their command and control systems. At least in one known case—and most probably in several other cases, as hinted at by people in the know (for instance by responsible individuals who served as Ministers of Defense in key nuclear-weapon countries; indeed, some of these cases are widely known)—a catastrophic nuclear exchange was only avoided because an individual—Colonel Stanislav Efgrafovich Petrov—took upon himself the responsibility to disobey orders and not to launch the nuclear-armed missiles under his command, in spite of the evidence that a nuclear attack was incoming. Indeed, the operational rules implied by deterrence theory required that those missiles be launched before being destroyed by the incoming missile attack; thereby providing just that nuclear response the threat of which was supposed to deter the nuclear attack that—in that specific case—was, by all available evidence, in progress.

So, the world was saved from a sudden nuclear catastrophe. Due to the good sense of a single individual.

An individual who, incidentally, behaved in the most "reasonable" manner: by deciding not to launch the missiles under his operational command he opted for the—supposedly "impossible"—chance that the warning of the incoming nuclear missile attack was just due to a mistake, and as a fateful consequence of his decision he and many others did survive (of course he himself might then be shot for not having followed his instructions…); while in the alternative case (no mistake of the warning system, the incoming attack was indeed incoming) he would in any case be incinerated (with his colleagues, and many others). So, his decision was indeed a quite reasonable decision: especially in the context of that cold logic that is supposed to subtend nuclear deterrence theory and the consequent rules governing the operational employment of nuclear weapons (with no place for ethical or humanitarian considerations).

In fact, he was not subsequently shot; nor were shot—as far as I know—those who had designed a deterrence mechanism that was designed so as to produce an unnecessary catastrophe, thereby demonstrating the criminal idiocy of its planners.

When fools are in charge of critically important planning concerning the employment of weapons of mass destruction, we must worry; but we can have little hope of redress after we witness that theories which are both foolish and dangerous continue to provide the dominant paradigm of the thinking about the operational command and control of nuclear weaponry. Or when totally childish statements are uttered by key decision makers bragging about having a bigger organ, with reference to the size of the nuclear arsenal of which that decision maker is (in principle) ultimately in control.

My conclusion is that we must all try and fulfill the responsibility to point out that a world with large numbers of high-yield nuclear weapons the purpose of which is—without being used; just by their presence—to deter the use of nuclear weapons by potential enemies; such a world has now been shown to be based on stupid rules: survival has been experimentally demonstrated to require that those rules not be followed! The rules meant to implement nuclear deterrence being clearly foolish, the “enemy” has every reason to expect that they in fact shall not be implemented: hence there is no logic in the claim that deterrence over time worked, since the world was spared the actual use of nuclear weapons *in bello* for over 70 years. In fact, the world has not witnessed a catastrophic employment of nuclear weapons—after Hiroshima and Nagasaki—not thanks to nuclear deterrence, but in spite of nuclear deterrence: only because the rules meant to implement nuclear deterrence were not followed. And note that this clearly indicates that the eventual planner of a nuclear attack may well expect that there shall be no nuclear retaliation; or at least that this is not likely to happen, being a quite irrational act.

Yet the myth of the effectiveness of nuclear deterrence continues to be instrumental to sustain the development and deployment of nuclear weaponry; and the belief of its relevance is perhaps the main cause impeding progress towards the elimination of nuclear weaponry: the eventual actual employment of which constitutes the major threat to the survival of our civilization, perhaps of *homo sapiens*.

Moreover, it now begins to be—quite logically!—suggested that, in order to guarantee that the threat of catastrophic retaliation on which deterrence theory is based is a certainty, its implementation should be turned over to intelligent computers, so as to eliminate the unreliable intervention of humans and thereby make it quite certain that nuclear deterrence work! Opening eventually the way to interventions of more intelligent hackers.

Our current scientific understanding of cosmology and of the emergence of intelligent life on our planet is not sufficient to make reliable estimates of the probability that other intelligent communities exist in the universe; so there is no cogent scientific reason to be surprised by the fact that so far we got no signals indicating their existence. Yet a reasonable conjecture is that this may be due to the fact that all sufficiently intelligent civilizations which emerged in our universe, eventually discovered enough about microphysics to become able to manufacture nuclear weaponry; and then eventually these weapons were accumulate and used; and this “inevitable” development caused the disappearance of that civilization. So, this seems our ultimate fate.

Indeed, the task to eliminate nuclear weapons—before they eliminate us —is by no means easy in the current world context. Important progress in this direction had been made, perhaps culminating—a decade ago—in the statement by President Obama in Prague (April 9th, 2009): [...] So today, I state clearly and with conviction America’s commitment to seek the peace and security of a world without nuclear weapons. This goal will not be reached quickly—perhaps not in my lifetime. It will take patience and persistence. But now we, too, must ignore the voices who tell us that the world cannot change. We have to insist, "Yes, we can." […].

But in the last decade there has been regress, motivating the pessimistic conjecture that significant progress shall occur only after a major nuclear-weapon catastrophe.

Yet all of us—and primarily all those of us having some specific competence or professional involvement in the development and operational management of nuclear weapons (their technologies, their operational rules, and the related domestic and international politics)—all those who sincerely believe that their activities related to nuclear weaponry help to promote the survival of their fellow citizens and of humankind—we all ought to recognize and advertise the demonstrated, dangerous folly of nuclear deterrence theory and of the military doctrines and operational rules implied by it; trying moreover to cooperate in order to move humankind back from the brink of nuclear annihilation.

A final warning. If you suspect that the point of view expressed above about the current operational aspects of nuclear deterrence is excessively alarmistic, you are advised to read the short paper (dated September 10th, 2019; available from the website of the Carnegie Endowment for International Peace) entitled "A Commonsense Policy for Avoiding a Disastrous Nuclear Decision", authored by James A. Winnefeld, who served as the commander of NORAD (North American Aerospace Defense Command) and who retired in 2015 as the ninth Vice Chairman of the USA Joint Chiefs of Staff. Its 3 sections—entitled "The current command-and control system is under stress", "How the current system might fail", and "How a decide-under-attack option would work"—are a terrifying description of the current operational situation and of the strategic thinking underlying the actual employment of nuclear weaponry, as described by someone who has been until rather recently in charge of it in one of the two nuclear-weapon superpowers. Indeed, the diagnosis of the risks of the current situation is, coming from such a competent source, quite compelling. While the proposed improvement—"reasonable" as it is in the framework of the deterrence ideology—demonstrates a remarkable frame of mind (an occupational disease?): four alternative scenarios are envisaged, two of which are viewed as, in some sense, "successful", including the one resulting in a full nuclear annihilation having the dubious merit to be symmetrical hence more universal (and, by the way, demonstrating a catastrophic failure of deterrence).

# Chapter 7
# Nuclear Weapons, International Security, and Non-proliferation in the 2020s

**C. S. Eliot Kang**

Thank you for having me here in Rome to address nuclear weapons, nonproliferation, and the broader security environment. I would like to focus my remarks on our new initiative to launch a structured international dialogue on Creating an Environment for Nuclear Disarmament, or CEND. This is a topic of great interest to my boss, Assistant Secretary Chris Ford, who is unable to be here today. He sends his regrets.

Before I outline the CEND initiative, I would like to put it into context. This initiative emerged from the review process for the Nuclear Non-proliferation Treaty, or NPT. March 5 will mark the 50th anniversary of the NPT's entry into force, and the tenth NPT Review Conference will take place next April to May. These milestones are an opportunity to recall how the NPT has made the world safer and more prosperous. It is difficult to imagine how the world might have evolved without the NPT, how many states might now possess nuclear weapons, and how much more fraught it might be to pursue the peaceful uses of nuclear energy, science, and technology. This anniversary is also an opportunity for states to reaffirm their commitments to the Treaty, and to rededicate themselves to preserve and strengthen the nuclear nonproliferation regime for future generations.

NPT Review Conferences take place every five years. They are often quite contentious and feature sharp divisions among various groups of states, in particular over nuclear disarmament. You could be forgiven if you had the mistaken impression of a treaty in crisis. But you would be mistaken to focus on these divisions and ignore how much the NPT actually represents the common interests and aspirations of all of its Parties. All NPT Parties—nuclear-weapon states and non-nuclear-weapon states alike—are made more secure by an effective nonproliferation regime that prevents the further spread of nuclear weapons. The assurances provided by that regime facilitate peaceful nuclear cooperation and help create a security environment conducive to progress on nuclear disarmament. Nonproliferation, disarmament, and peaceful

C. S. Eliot Kang (✉)
US Department of State, Washington, DC, USA
e-mail: morrellts@state.gov



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uses of nuclear energy are not competing interests but shared benefits for all NPT Parties.

The past 50 years have seen significant progress on nuclear disarmament. The United States has reduced its total stockpile of nuclear warheads by approximately 88% from its Cold War peak, from 31,255 nuclear weapons in 1967 to 3822 as of 2017. Many categories of nuclear weapons have been removed from our stockpile altogether. However, the dramatic reductions in nuclear arsenals that took place when Cold War tensions eased have largely run their course, and security conditions have become much less favorable. The long list of challenges includes long-running regional tensions in South Asia, the Middle East, and elsewhere. Some nuclear-armed states are modernizing and expanding their nuclear capabilities at the same time they are becoming increasingly assertive in challenging the existing international order.

The CEND initiative grew out of an effort to think creatively but realistically about how to move forward on nuclear disarmament in light of these challenges. It seeks to establish a dialogue on how all states can work together to create an environment conducive to further progress on nuclear disarmament. The CEND Working Group (CEWG) met in Washington, DC, July 2–3. Its primary goals were: first, to identify a list of challenges that would need to be overcome or questions that would need to be answered in order to create an environment more conducive to progress on nuclear disarmament; second, to establish and define an initial mandate for subgroups to examine those factors and questions; and third, to determine subgroup composition including co-chairs.

Non-governmental expert facilitators from the Carnegie Endowment for International Peace, King's College London, and the Clingendael Institute guided breakout sessions focusing on three themes. The first theme was reducing perceived incentives for states to retain, acquire, or increase their holdings of nuclear weapons. Participants decided to broaden the topic to address the converse: increasing incentives to reduce and eliminate nuclear weapons. The second theme was multilateral and other types of institutions and processes to bolster nonproliferation efforts and build confidence in, and further advance, nuclear disarmament. The third theme was interim measures to address risks associated with nuclear weapons and to reduce the likelihood of war among nuclear-armed states.

Over the course of the two-day conference, the NGO facilitators worked with each of the breakout sessions to identify areas of convergence for further work by subgroups. These areas of convergence were based on the observations of the facilitators and not necessarily the consensus views of the participating governments. To enable an open dialogue, it was necessary to limit the number of countries participating in the initial CEWG meeting, but in order for this effort to be taken seriously, we brought together an ideologically and geographically diverse group of countries to form the core group of CEWG participants. We achieved this, with participants hailing from 42 countries across the globe and representing governments that are both likeminded with our positions, as well as those with whom we have significant differences. All five NPT nuclear-weapon states—the P5—took part in this meeting, including my fellow panelist Vladimir Leontiyev.

While the CEND initiative was motivated by a desire so stimulate a more realistic approach to disarmament in NPT-based deliberations, it has implications beyond the NPT. In addition to the P5—the NPT nuclear-weapon states—India, Pakistan and Israel, which are not NPT Parties, were active participants in the first meeting. For too long, the international disarmament discourse has focused almost exclusively on the P5. This ignores the obvious fact that even if the P5 eliminated all their weapons, the result would not be a nuclear weapon-free world. If we are to take the issue of nuclear disarmament seriously, then we need to involve states outside the NPT as well, for these states are located in regions where some of the most intractable obstacles to disarmament lie.

Every country has a stake in the dialogue around nuclear disarmament. CEND's success depends upon the active engagement of countries participating directly in the CEWG and helpful input from those not directly participating. We continue to encourage consultations by CEWG participants with other states in their respective regions. In particular, we have consulted with NATO Allies in Brussels before and after the first CEWG meeting.

Within the CEWG, deliberations took place under the Chatham House rule. Participants are free to discuss views expressed during the meeting, but should not attribute them to a particular speaker or country. And the views expressed do not necessarily coincide with those of the United States. With that in mind, I would like to simply list some of the areas of convergence within each of the topical subgroups.

The first subgroup addressed "reducing perceived incentives for states to retain, acquire, or increase their holdings of nuclear weapons and increasing incentives to reduce and eliminate nuclear weapons". It identified the following potential areas for further work:

- Articulate threat perceptions of states in regional (or global) competitions involving nuclear weapons more clearly and deeply so they can be better understood and addressed,
- Buttress existing arms control, nonproliferation and security mechanisms and compliance with them,
- Assess differing perceptions of the purpose of declaratory policy, including for deterrence and reassuring those most alarmed about the prospect of nuclear war,
- Improve capabilities and protocols to verify nuclear disarmament and
- Address the tensions between nuclear deterrence and concerns over the humanitarian consequences of nuclear war.

The second subgroup addressed "multilateral and other types of institutions and processes to bolster nonproliferation efforts and build confidence in, and further advance, nuclear disarmament". The following areas of convergence for further work emerged:

- Strengthen and maintain existing institutions through preserving what we have, maintaining the disarmament architecture, and avoiding politicization of existing institutions and agreements,

- Strengthen and reaffirm commitment to the NPT by monitoring progress with existing commitments and acknowledging the NPT is the "cornerstone" of the global nonproliferation and disarmament architecture, and
- Develop a list of practical measures with a view to improving the security environment through focusing on nonproliferation measures, building trust and confidence, and identifying what is practical now.

The third subgroup considered "interim measures to address risks associated with nuclear weapons and to reduce the likelihood of war among nuclear-armed states, and found the following areas of convergence:

- Reduce the likelihood of nuclear weapon use through conflict management and prevention,
- Build trust through transparency and confidence building measures in the area of risk reduction, and
- Improve communication and dialogue among states possessing nuclear weapons and between states possessing and not possessing nuclear weapons.

We are now turning to next steps, including convening a second CEWG meeting, which will take place November 20–22 at Wilton Park in the UK, by invitation only. All three subgroups will meet. This will allow for greater cross-pollination between subgroup discussions and should also allow participating countries to cover all three subgroups with one or two representatives. Subgroup co-chairs will play an important role in making this and subsequent meetings successful. The Netherlands is co-chairing the "reducing incentives" subgroup, with the other co-chair still to be confirmed. South Korea and the United States will co-chair the "nonproliferation institutions" subgroup. And Germany and Finland will co-chair the "risk reduction" subgroup.

We are also working to enlist NGO support as part of a consortium approach. NGOs would provide needed resources to the CEWG process, including by assisting the co-chairs and by facilitating discussions, but the substantive discussions will continue to take place only among government delegations.

Before I close, allow me to say a few final words about the goals of the CEND initiative in the NPT context. By the 2020 NPT Review Conference, subgroups will have met in person at least once more, with associated intercessional work being conducted between meetings. We do not plan for the CEWG to have completed a "phase" of its work before the RevCon, as that is an unrealistic timeline for the CEWG to have developed finished deliverables for the serious and difficult work it is tasked with. However, by the RevCon, CEWG subgroups will have clearly outlined their plans of work. At the RevCon, the CEWG subgroup co-chairs will be able to present a clear plan for progress that will continue past the 2020 RevCon. We envision holding a side event to lay out these plans.

In closing, I want to emphasize two key points. First, the US government fully supports this initiative. But second, we have no intention to micromanage its proceedings or prejudge its outcomes. We received uniformly positive feedback from our first meeting, thanking us for the deep, substantive interactions of our first meetings, which allowed participants to get past their standard talking points and develop a real understanding of each other's perspectives. We aim to build on that foundation. Ultimately, it is up to the participants to determine the direction that these dialogues take.

# Chapter 8
# Russia's Vision for Arms Control, Disarmament, and Non-proliferation

**Vladimir Leontiev**

Russia's vision of arms control, disarmament and non-proliferation issues remains in fact very conventional. It is pragmatic and realistic and has no ambition to look "innovative", "forward-looking" or "future-oriented". We do not feel "constrained by traditional formats and diplomatic protocol", as our American colleagues sometimes are. On the contrary, we strongly believe that in many cases using proven formats and keeping to well-established diplomatic routine is the best way to address and resolve outstanding international issues of today and tomorrow. From our point of view, this "traditionalist"—or maybe "no-nonsense"—approach may be helpful for preventing turning serious and solution-oriented professional discussions aimed at achieving substantive results into road-shows with uncertain purpose, random participation and no clear mandate.

We also do not see advancing arms control, disarmament and non-proliferation as a self-sufficient goal. For us, it is first of all one of the means to assure Russia's national security—in this case, by using political and diplomatic tools. The Foreign Policy Concept of 2016 specially emphasizes this particular function of Russian diplomacy and gives it an undisputable "number 1". So, we have a strong conviction that national security is—and should be—the main driving force behind this process. By the way, this concept is also reflected in the NPT review disarmament-related formulas "in a way that promotes international stability, peace and undiminished and increased security" and "based on the principle of increased and undiminished security for all".

As a matter of fact, it would be completely unreasonable to expect any automation or self-sustained dynamics in areas, where progress depends on and is determined by evolving security environment. And evolutions that we currently see are anything but encouraging.

Smart and honest diplomacy can achieve many things. Sometimes it can succeed even without "touching neither a cannon nor a ruble", as Russian poet and diplomat

V. Leontiev (✉)
Minsitry of Foreing Affairs, Moscow, Russian Federation
e-mail: dnkv@mid.ru



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Fedor Tiytchev has put it in December 1870. Though this formula dates from the XIX century, it still remains relevant and is fully applicable today, when military build-ups and deployments are often considered to be an efficient method of resolving outstanding issues, and when ideas like "peace through strength" and "strong powers competition" are becoming alarmingly popular in certain parts of the World. This is disturbing, because all previous attempts to achieve peace through strength have notoriously failed, and competition is hardly an appropriate basis for building stable and cooperative relationships.

In the field of arms control, disarmament and non-proliferation Russia is strongly committed to traditional legally-binding instruments, that is to say international treaties and agreements. From our point of view, they have clear advantage over "Rules based order" and over unilateral measures, informal understandings or even political commitments, though sometimes these may also be useful.

First of all, legally-binding instruments result from negotiations during which parties directly express their concerns and formulate their wishes. This allows to address real issues without too much bias—at least in theory, for we have recently witnessed some quite different examples—and to reach a realistic balance between what is desired and what is achievable. This also provides opportunity to develop appropriate verification machinery and to agree on scope and modalities of eventual outreach. This aspect becomes particularly important today given—for example—growing aspirations of non-nuclear weapon States to monitor and verify the process of nuclear disarmament, that is to say reductions and limitations of nuclear weapons carried out by NWSs.

Verification is really one of the strongest points of legally-binding arrangements that no external oversight may substitute. Those familiar with our nuclear arms reduction treaties with the USA know that they are largely about verification. These treaties, surely, contain benchmark figures and dates as well as things like databases and glossaries of terms and definitions, but almost all the rest of their volume is dedicated to verification and transparency. By the way, problems that we currently have with New START Treaty implementation by the United States relate exactly to this particular area.

Unilateral measures do not even come close to these standards. For instance, a country may declare it has unilaterally reduced its nuclear missiles to a number of "X'. The first question is—how do we know it is true? And how the accuracy of such data may be checked? As a matter of fact, there is nothing to support such claims except "you have my word". Sounds great and sincere, but doubt may still exist, and there is no practical way to dissipate it.

On the contrary, treaties like New START allow to track any particular missile or any particular launcher throughout its entire life-cycle and to have an accurate count of deployed nuclear warheads or other treaty-limited assets, even if sides may disagree on their actual numbers, as they do now. They may also contain mutually agreed guidelines and rules for eliminations or eventual conversions, so that one may be sure about the result of procedures applied. This is at least how it is supposed to work.

Legally-binding international instruments are also more difficult to cancel, even though treaties typically contain an "escape close" allowing each party to withdraw if it decides that extraordinary events related to the subject matter of the treaty have jeopardized its supreme interests. Fortunately, in the area of arms control using this clause is rather rare. Two major examples are the US withdrawals from ABM and INF treaties that we deeply regret. Such steps may bring freedom for realizing certain military programs and create an illusion of securing an advantage, but they inevitably produce very harmful consequences for international security and stability. At the USMC they say, that if something is done twice, it becomes a tradition. This gives me real concerns about the New START—the last nuclear arms control treaty involving the USA that remains and that is getting nowadays strong criticism in Washington DC. Tradition is already there, so there are reasons to expect this Treaty might be next on the list. I do hope our American colleagues do not intend to cross this box as well and will allow the Treaty to live at least to its regular term in February 2021. But frankly, I am not sure.

All these concerns exist and are well-founded. Nevertheless, presence of legally-binding framework can make situation in the area of arms control, disarmament and non-proliferation more stable and more predictable. And this is something it badly needs today, when acute problems arise and when we face systematic attempts by certain States to disrupt fundamental arms control agreements and regimes and to convert the entire international arms control architecture to fit their particular interests. Aspirations for military domination and search for tools that would allow stronger pressure on political opponents or "competitors"—to use a more "trendy" expression—result in scrapping mechanisms that have been contributing to maintaining international security and stability for decades.

The most recent example was scrapping the INF Treaty. It is clear for us that the real purpose of the pathetic set-up related to this Treaty was to create an opportunity to get rid of its restrictions and to clear ground for building additional military capacity intended first of all to exert pressure on China that the US believes to be its major military opponent and economic competitor. At a certain point INF Treaty became an obstacle, so this obstacle was removed.

Similar reasons may explain persistent ambiguity concerning prospects of the New START Treaty. Russia has come out for its extension. We think that under present circumstances this would be a reasonable solution, for it is clear that remaining time is already too short for negotiating a follow-up agreement, and that otherwise in just sixteen months we will remain without any means at all to ensure mutual transparency and predictability between our two countries in the area of strategic nuclear weapons. Extension would maintain the existing regime of regular data exchanges, notifications and inspections that Russia and USA carry out at their respective military facilities. It would also buy time for addressing the issue of new weapons and technologies and eventual arms control measures that might be applicable to them. This is an important subject that we are ready to discuss with our American colleagues in the framework of our bilateral strategic dialogue.

But before extension is considered, there is an urgent need to settle the issue of illegitimate withdrawal by the USA from the accountability under the Treaty of a significant number of its strategic assets that the American side has either unilaterally declared “converted” or simply renamed using language that is not in the Treaty. It is as if calling a “ballistic missile” a “self-propelled flying bomb” would exempt from the Treaty all Russian and American ICBMs and SLBMs as well as their launchers. It is an interesting idea, but quite evidently it would deprive the New START—or any other similar treaty—of any practical sense.

The New START Treaty provides for eventual conversion of certain categories of SOAs, rendering them incapable of employing nuclear armaments, but it stipulates this should be done so that the other Party can confirm the results of the conversion. Then they stop to count against agreed central limits. Our American colleagues have ignored this rule and today they exceed Treaty limits by more than one hundred accountable units—SLBM launchers and HBs. If this capacity is recounted into actual nuclear warheads, it will give the USA a more than comfortable advantage of 1200. Way too much for a Treaty that allows each side to have no more than 1550. We insist the American side should implement the Treaty the way it was negotiated, signed and ratified, but colleagues do not recognize that they have a problem and insist on their right to read this bilateral agreement in their very special way that we believe is completely wrong. We will continue working with the US on this issue.

The NPT is also under pressure. This cornerstone Treaty is strongly affected by growing estrangement between nuclear- and non-nuclear weapon states supporting different approaches to nuclear disarmament. To make things worse, situation is aggravated by revisions of previous arms control commitments and dismantlement of landmark agreements taking place against the background of attempts by certain States to turn the Treaty into a political tool serving their purposes. Sometimes these purposes have little or no relation to nuclear non-proliferation. For instance, during the current NPT review cycle on several occasions discussions were initiated on chemical weapon attacks, while the issue of chemical weapons is absolutely strange to this Treaty.

One more negative factor affecting the NPT is the perpetuation of NATO’s “nuclear sharing” arrangements that go against the Treaty’s Article I and Article II. There is no doubt this issue of “nuclear contamination”, as it is called at the NPT RevCons, will be raised once again at the coming Conference in May. Besides Russia’s concerns, it is one of the favorites for NAM countries that certainly will not miss such an occasion. And they will be right to do it.

Neither should we forget other long-standing controversial topics on the NPT agenda, such as overinflated nuclear disarmament expectations that gave birth to the Treaty on prohibition of nuclear weapons (TPNW), lack of progress on the Middle East NWFZ, unresolved regional issues (Iran, DPRK) etc.

All this will surely make the 2020 RevCon anything but a piece of cake, but Russia is fully committed to its success. We will work hard to achieve positive outcome. Our strong belief is that everything should be done to assure unfailing viability and efficiency of the NPT. This goal is our top non-proliferation priority, and so it will remain.

Another matter of big concern is CTBT. The US decision not to ratify it has created a very awkward situation. On one hand, the Treaty is signed by 184 countries and ratified by 168. Data from International Monitory System is being acquired, transmitted and analyzed, though efficient full-scale functioning of the Treaty's verification machinery requires its entry into force. On the other hand prospects for this Treaty to enter into force look pretty dim now. Nevertheless, Russia supports the list of measures intended to facilitate its entry into force that was adopted in New York on September 25th, and we will actively participate in their implementation.

Naturally, we have noticed recent American accusations that Russia is non-compliant with this Treaty. First of all, a State that has refused to ratify CTBT and to assume respective legal obligations has no formal or even moral right to speculate about such issues. But given the US record we suspect that there is something more here than regular Russia-bashing and that our American colleagues may be preparing appropriate environment for eventually recalling their signature and resuming nuclear tests. This would be another hard blow for international security and nuclear non-proliferation.

One of Russia's strategic stability and arms control everlasting headaches is the US missile defense shield. Since Washington pulled out of the 1972 ABM Treaty some twenty years ago missile defense assets and technologies are free from any political and legal constraints and are being developed in the most destabilizing way undermining international security and entailing emergence of new generation of weapons specially intended to overrun them. And it is not only about Russia. NATO is also striving to create a capacity that would allow it to penetrate what is called "AI/AD domes" that is, to engage and destroy on Russian territory targets protected by AA and MD. So, this problem works both ways meaning it requires common attention.

New reasons for trouble appear as plans are announced to deploy missile defense interceptors in space and to carry out missile defense by preemptively hitting adversary missiles on the ground "left to launch". People who promote such ideas should remember that this particular logic of "preemptive disarming first strikes" has generated the multiplication of "counterforce" nuclear scenarios that were fueling the arms race for decades and that have repeatedly brought the World to the brink of overall nuclear war.

Returning to such scenarios may look like a medical case, for one of the symptoms of mental disorder is repeating the same action again and again expecting to get a different result. There will be no different result. The only way to alleviate the threat of preemptive strikes is to build up the number of assets, make them more survivable and launch them as soon as possible with the first hints of being under attack. I think that one of the biggest strategic concerns of our American colleagues is to avoid what they call "unwanted escalation". Nevertheless, it seems that in this case it is exactly the 'unwanted escalation" that is looming. Especially given the fact that if the New START is not extended, there will be no numerical restrictions preventing eventual build-ups.

"Power competition" does not really go well with maintaining strategic stability and promoting arms control, for "competition" is inevitably based on race for superiority "in the air, on land and sea"—or in space. We think that such attitudes are behind the staunch opposition to russo-chinese draft proposal of a treaty prohibiting placement of weapons in space and to our initiative of making unilateral commitments not to be the first to place weapons in space, that are intended to prevent space becoming a new field of the arms race and to avoid it being "dominated" by anybody. Especially when it is the question of military domination.

Russia is strongly opposed to diverting international arms control and non-proliferation regimes from their initial legitimate purpose and turning them into political tools serving the interests of individual States or groups of States. Sad results of such an abuse may be seen at the OPCW that some member-states wanted to integrate into their campaign against Syrian President Assad and his government. Another goal was to blackmail Russia and to undermine our efforts aimed at political settlement of the conflict. To do it, the OPCW technical secretariat—administrative body by definition—was invested with "attribution" functions empowering it to designate perpetrators of eventual chemical attacks. This was done in a very irregular way circumventing the rules set by the CWC. There is no doubt this mechanism will work "as instructed" by its major stakeholders and produce conclusions that they expect.

Russia will continue to oppose this plot. We call on all the OPCW member-states not to undermine this Organization that until recently was one of the most successful and efficient mechanisms in the area of disarmament and non-proliferation.

For Russia, the central role in strengthening the global architecture of arms control, disarmament and non-proliferation should belong to the UN and its multilateral disarmament machinery. Unfortunately, here we also witness disturbing trends that risk reducing to zero the efficiency of what is called "the UN disarmament triad". The GA voting results for relevant resolutions show that consensual decisions are getting more and more difficult to achieve and that there is no common program of action in this area. Even issues that formerly seemed to be undoubtedly unifying may suddenly become objects of bitter controversy. Attempts to sideline substantive dialogue, to politicize debates and to turn the UN into a tool for building pressure on opponents became especially manifest during the 2018 session of the UNGA First Committee.

Speaking of the UN I can not avoid mentioning scandalizing and totally illegitimate US refusals to issue visas to members of Russian delegations and Russian experts coming to the UN events being held in NY. Such US policy is an open incompliance with its commitments under the 1947 Agreement on the UN headquarters. This year it has resulted in disrupting the regular session of the UN Disarmament Commission by preventing the head of the Russian delegation from attending it. Thus American authorities have shown their real priorities as they have collapsed discussions on the issue of transparency and confidence-building measures in outer space activities that were originally initiated by the US side.

Current situation in the UN disarmament machinery reflects general deterioration of international situation that is aggravated by lack of dialogue on strengthening the existing arms control, disarmament and non-proliferation regimes and on developing mutually acceptable new mechanisms in this area. In this context, the issue of a legally-binding Protocol to the BTWC is a tattle-tailing example of how things may get blocked by those who want to avoid restrictions and constraints—or, maybe, have something to hide.

Speaking of BTWC, Russia will continue to support initiatives aimed at strengthening its regime and making the Convention more efficient. We have made a number of proposals in this sense and call on all other members to support them. But the issue of the Protocol is still pending.

Under current circumstances it is very important to keep the remaining communication channels open. We are glad that after a long—maybe, too long—break strategic dialogue has resumed with the USA. It is a venue that allows us to speak openly on our respective security concerns and on eventual ways to fix them. We are looking forward for the next meeting that we hope will take place before the end of this year. Bilateral high-level discussions with some other countries also take place.

For Euro Atlantic region an important role in this area belongs to OSCE Forum for Security Co-operation, "structured dialogue" on European security challenges and threats and the Open Skies Consultative Commission. The NATO-Russia Council that was supposed to be "weather-proof" has failed a real-life test. Its NATO members did not realize that dialogue is only possible on the basis of equality and mutual respect. So, now NRC is practically out of business, and there are strong doubts about its future.

Within the OSCE framework Russia's priorities are reducing military confrontation, including mutual restraint in military activities along our borders with NATO countries, resumption of military-to-military contacts, risk reduction, strengthening stability and de-escalation. As for "structured dialogue", it first of all provides us an opportunity to address issues related to "deconflicting".

Surely, international security and arms control agenda in Europe may be much more ambitious. I am not speaking about the "European missile crisis Rev 2.0" that may be coming our way. There are lots of things here that can be done on a cooperative basis. We have already kissed some of these "sleeping beauties", but they either did not wake up, or went to sleep again. Maybe, second chance will be worth trying, but for this it will be necessary to return to the basics and assume that all countries here are equal. They all have their security concerns and legitimate security rights. Russia is not an exception. One should also remember that arms control is always a deal, so it would be totally unrealistic to expect us to give away our national security interests for nothing. And, most of all, it is important to realize that nothing positive will ever be achieved through policies of "deterring Russia", that nowadays look more and more like "containment" that was the central element of the Cold war, and that, I hope, we have definitively left behind.

# Chapter 9
# Perspectives on Nuclear Safety, Security, Safeguards and Non-proliferation

**Li Hua**

*Global nonproliferation and nuclear security and safety situation remains facing challenges*—The global situation on nuclear non-proliferation, nuclear security, and nuclear safety presently remains facing considerable uncertainties. The Korean Peninsula nuclear issue, although achieved some progress over the year 2018, still in the jeopardy of increasing tension escalations in the wake of the Hanoi Summit ending up without further agreements. The recent tests of the DPRK's short-range missiles have provided more uncertainties for the future of the Korean Peninsula situation. Meanwhile, the Iran nuclear issue is confronting severe challenges. The Trump administration's withdrawal from JCPOA, as well as its revival of sanctions against Iran, has inevitably triggered an increasingly intense confrontation between Iran and the United States, fueling regional tensions and conflicts risks. Nuclear proliferation risks have been increasing featuring as some country has accumulated a large amount of sensitive nuclear materials in the operation process of nuclear power industries which could serve for proliferation purposes. Some emerging technologies are contributing to the proliferation risks growth by facilitating wide-spreading nuclear weapon design knowledge and lowering nuclear devices design and production thresholds. More broadly, the global development of nuclear power industries would inevitably be coupled with the risks of proliferation due to the dual-use nature that nuclear technologies possess.

*Chinese approach to address challenges of nuclear proliferation, safety and security*—China is facing an extremely complicated situation both in domestic and abroad. The Korean Peninsula nuclear issue is in the vicinity of Chinese territory, which could deliver a considerable impact on Chinese national security. There has been a considerable amount of sensitive materials in China's neighboring counties, leaving China facing potential proliferation threats. Chinese nuclear power industries

L. Hua (✉)
China Academy of Engineering Physics, Beijing, People's Republic of China
e-mail: lihuaw@iapcm.ac.cn



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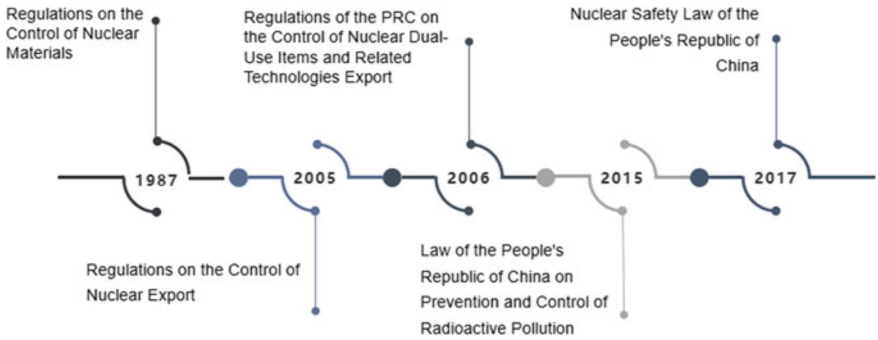
have been undergoing rapid developments with about 11 nuclear power plants under-construction simultaneously, ranking the global top. The facilities would be possibly become the targets of nuclear terrorism, resulting in emerging nuclear security challenges.

Addressing the complicated threats and challenges of nuclear security, safety and proliferation requires strategic thinking and concrete measures, The Chinese ancient culture has provided the general guidance for managing the complicated risks of proliferation, safety, and security, which could be dated back to the philosophy of Confucius and Laozi about 2500 years ago. There is a Chinese character that could be used to convey this idea, which is 和, whose primary meaning is harmony. Chinese ancient philosophists raised great ideas featuring compatibility between peoples and between people and nature. For personal relations, this idea highlights no impose on others; For relational between people and environment, it highlights the integration between the two and the compliance with natural patterns.

To address the imminent domestic threats and challenges, China has adopted a Rational, Coordinated and Balanced Nuclear Safety Strategy, which highlights equal emphasis on development and safety, and develop the nuclear industry in a context of guaranteed safety, equal emphasis on rights and obligations, and promote international nuclear safety on the basis of respect for the rights and interests of all countries, equal emphasis on independent efforts and coordination, and seek universal nuclear safety with a mutually beneficial approach and equal emphasis on symptoms and root causes.

China has attached great importance to the building of legal framework consisting of the laws on nuclear safety, under which administrative regulations and departmental rules dovetail with the law, the provisions of laws and regulations and technical standards complement each other. In June 2003, the Law of the People's Republic of China on the Prevention and Control of Radioactive Pollution was promulgated; in September 2017, the Nuclear Safety Law of the People's Republic of China was issued. By June 2019, China had enacted nine administrative regulations such as the Regulations on the Supervision and Administration of Civil Nuclear Facilities, the Regulations on the Supervision and Administration of Civil Nuclear Safety Equipment, the Regulations on Nuclear Material Control, and the Regulations on Emergency Management of Nuclear Accidents at Nuclear Power Plants. It had issued over 30 sets of departmental rules and 100 sets of safety guidelines, and formulated over 1000 national and industry standards related to nuclear safety.




Milestones of China's Building of Legal Structure on Nuclear Non-proliferation and Nuclear Safety and Security

Governance capabilities, under the legal guidance, are essential to ensure the enforcement of the strategies as well as the legal instruments. China has constructed a three-pronged regulatory system consisting of headquarters, regional offices and technical support organizations and developed a whole set of regulative regimes which includes comprehensive review and license management, whole-process surveillance and law enforcement, round-the-clock radiation environment monitoring, improved nuclear and radiation emergency response and professional teams.

China's increasing embrace of global nuclear governance marks another Chinese effort to enhance its capabilities to confront nuclear proliferation, safety, and security challenges. China joined the Zangger Committee in 1997 and The Nuclear Supplier Group in 2004 respectively and signed with the IAEA the safeguard protocol in 1998. China in 2008 decided to ratify the amendment of Convention on Physical Protection of Nuclear Materials.


Milestones of China's Participation in Global Governance on Nuclear non-proliferation and Nuclear Safety and Security

Chinese nuclear scientists community has launched a variety of research programs on nuclear non-proliferation, nuclear safety, and security and has been conducting dialogues and communication broadly with international colleagues in the area. Chinese scientists in organizations such as China National Nuclear Cooperation, China Institute of Atomic Energy and China Academy of Engineering Physics have done nuclear material composition analysis through destruction analysis technologies such as X-ray fluorescence analyze and mass spectrometry, uranium enrichment, and plutonium isotope composition through non-destruction analysis technologies such as gamma spectrometry. Chinese scientists employ numerical modeling and Monte Carlo method to simulate nuclear reactors' operation and developed sensitive material detection and vehicle monitoring, which contributes to addressing nuclear material smuggling challenges.

The creation of China-the United States Center on Excellence has marked one of the great highlights in China's cooperation and collaboration with partners worldwide. During the Washington Nuclear Security Summit in April 2010, the former President Hu Jintao reached an agreement with then President Obama on the joint establishment of a Center on Excellence (COE) on Nuclear Security in China. The COE started operation in 2015 and has become a nuclear security exchange and training center boasting the enormous scale, the most comprehensive equipment, the most robust technical capabilities.

Through the systemic approaches, China has maintained a good nuclear safety record for a long time—it ranks among the highest of all countries in terms of nuclear power safety operation indicators. In 2000, 2004, 2010 and 2016, the International Atomic Energy Agency conducted four comprehensive reviews of China's nuclear and radiation safety regulation, giving full recognition to China's good practices and experiences. In the comprehensive ranking of similar units of the World Association of Nuclear Operators (WANO) in recent years, operating units in China have performed above the world median for more than 80 percent of the indicators, and have reached the world's advanced level for more than 70 percent of the indicators.

*Suggestions for further enhancing global efforts of promoting nuclear-nonproliferation, safety and security*—Nuclear proliferation and security and safety challenges are posing a shared threat to human community. Chinese President Xi Jinping stated in UN Geneva Office in 2017 that "Nuclear weapons, the Sword of Damocles that hangs over mankind, should be completely prohibited and thoroughly destroyed over time to make the world free of nuclear weapons". It is of great necessity that the international community should take joint measures to address the complicated situations concerning nuclear non-proliferation, nuclear safety, and security.

The Korean Peninsula nuclear issue remains one of the most severe items in international security agenda, which involves complicated domains such as security, politics as well as nuclear technologies. Furthermore, the possible denuclearization process would confront challenges such as declaration, dismantlement, disablements. The Chinese government has consistently advocated solving the complicated situation featuring the addressing symptoms and roots of nuclear proliferation, which means the security concerns and denuclearization demands should be addressed simultaneously. The dialogue and negotiation in this regard would be the most desirable approach. Moreover, given that the denuclearization process could be time-consuming, creative thinking is necessary to ensure the future possible denuclearization process could proceed smoothly. Deals on capabilities frozen, facilities disablements, weapons dismantlement could be reached respectively and separately.

The security mechanism building would be proceeded accordingly, possibly including confidence building measures such as exercise halt, exchange military posture information, and legally binding instruments such as peace treaty.

Given the indispensable role of sensitive nuclear materials in nuclear proliferation, strengthening nuclear sensitive material control would contribute significantly to reduce proliferation risks. The data from International Panel on Fissile Materials demonstrates that the global HEU inventory remains over 1000 tons with potential proliferation, nuclear security, and safety risks despite the significant improvements having been achieved in the reduction of HEU globally over Nuclear Security Summits, leaving considerable rooms to desire for further global efforts. The focus of efforts should be further orientated to reduce HEU usage with the highlight to promote the conversion of research reactors from fueling HEU to LEU. Plutonium would be the other focus of nuclear material control efforts. Spent fuel should be subject to international safeguards wherever possible and greater efforts remain in need of enhancing monitoring and detecting possible clandestine reprocessing facilities. Based on current researches and capabilities, Kr-85 remains the most reliable reprocessing indicator, and ariel random sampling is of more feasibilities than other means given that the required high-density network of fixed monitoring stations in the vast region would be prohibitively costly due to the Kr-85 background.

More theoretically, emerging technologies are dual-edged swords that could impact negatively on international security if proper management is absent. Global scientists community in this regard would be obligated to take enhanced approaches to take preemptive measures of risk management such as assessing proliferation as well as safety and security risks, promoting national legalization as well as participating in international cooperation.

# Part III
# Realizing the Promise of the Non-proliferation Regime Through Cooperation and Monitoring

# Chapter 10
# Introduction

**Marvin Adams**

Cooperation is central to the success of the non-proliferation regime, but we cannot simply assume that parties are cooperating. Monitoring helps confirm that countries are fulfilling their positive obligations to report stocks, technologies, and operations and their negative obligations to forego prohibited activities. Science and technology have long played important roles in monitoring treaty obligations, and as new technologies and analytical methods emerge and mature their roles can increase. However, neither development nor adoption is guaranteed. Technical developments require continued efforts by scientific and technical experts, informed by implementers and supported by adequate resources. Adoption and implementation of new technologies also require adequate resources and the shared will to enhance capabilities.

The international community relies on the International Atomic Energy Agency (IAEA), and particularly its Safeguards program, to confirm each country's compliance with its obligations under its comprehensive safeguards agreement and any additional agreements (such as an Additional Protocol) that expand the range of permitted inspections. As of 2019, 175 states have entered into comprehensive safeguards agreements with the IAEA, including all non-nuclear-weapon states party to the Nuclear Non-Proliferation Treaty (NPT) and all states party to regional nuclear-weapon-free-zone treaties. Under these agreements, the IAEA monitors activities to ensure that nuclear material is not diverted to a program for nuclear explosives. The IAEA also has voluntary agreements with the five NPT nuclear-weapon states and with India, Pakistan, and Israel, which are not parties to the NPT. The IAEA's most extensive safeguards efforts are currently in Iran, largely driven by requirements under the Joint Comprehensive Plan of Action (JCPOA). After operating for many

[1]Rotblat et al. [1].

M. Adams (✉)
Texas A&M University System, College Station, TX, USA
e-mail: mladams@tamu.edu



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years with the same technologies and approaches, the IAEA is now employing a variety of new technologies and using other extant technologies that have become feasible for the IAEA to use in conjunction with their traditional observations and analyses.

The ban on nuclear explosion testing, not yet in force but observed by all except North Korea, is a key element of the non-proliferation regime. The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) embodies both cooperation and monitoring and supports the non-proliferation regime. The CTBTO has a plenary body for deliberation and decision making and the Provisional Technical Secretariat, which conducts monitoring, processing and dissemination of data, and prepares for possible future on-site inspections. The CTBTO's capabilities have surpassed expectations, providing high-quality data and analyses of seismic events around the world, complemented by radionuclide detectors, and infrasound and hydroacoustic sensors. North Korea's violations of UN Security Council resolutions and international norms through nuclear explosion testing, as well as on-going production of fissile material and missile tests, have provided unfortunate opportunities for the CTBTO to demonstrate its capabilities, and it has performed well.

Detectors themselves have improved, but it is really the analysis of combinations of signals from detectors and sensors that has substantially improved monitoring capabilities. Artificial intelligence can help with these analyses. Multispectrum satellite imagery powerfully augments analysis using ground-based detection to compare to declarations. Technical advances for traditional monitoring can be complemented by nontraditional monitoring, which could include what Rotblatt called societal verification[1] and by what Stubbs and Drell called public technical means.[2] In the former, citizens of a treaty-bound country see it as their obligation to report publicly or to international bodies any potential violation of their nation's treaty obligations. The latter involves non-government analysis of open-source information. In both cases, technological innovation enables major improvements in the public's ability to assist the non-proliferation regime. But none of these advances comes without controversy.

The greatest recent advances in capabilities have come from integration of multiple sources of data. The CTBTO operates the International Monitoring System (IMS), data from which can be merged with data from national resources outside of the IMS. The IAEA now uses commercial satellite imagery extensively to analyze consistency. Together, these and other technologies make the non-proliferation monitoring regime more capable than ever before, and there are opportunities for further improvement.

[2]Stubbs and Drell [2].

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# Chapter 11
# The IAEA for Building Future Safeguards Capabilities

**Massimo Aparo**

*Mission*—The IAEA's verification mission for non-nuclear weapons states is derived from the Nuclear Non-Proliferation Treaty. That mission is a simple one: to verify—through the application of safeguards—that nuclear material within the territory, jurisdiction, or control of a non-Nuclear Weapons State is not diverted to nuclear weapons or other nuclear explosive devices. Our role is clearly defined in our statute and in legally binding safeguards agreements with States. We operate within boundaries largely determined by our Board of Governors - to provide a unique service to the international community.

Deterring the proliferation of nuclear weapons depends very much on the robustness of the verification regime. Essentially, there are three elements to a robust verification regime. First, for Member States to provide the IAEA with accurate and consistent declarations of their nuclear material and facilities. Second, having effective safeguards measures available. And third, having the will to apply them without fear or favour.

Verifying the non-diversion of nuclear material at declared nuclear facilities is an important element of that regime, but is not sufficient. Any determined proliferator is unlikely to conduct nefarious activities where inspectors regularly inspect. That is why we also need to provide credible assurance of the absence of undeclared nuclear material and activities. While the Agency has the "right and obligation" under Article 2 of the CSA to ensure that safeguards will be applied… on all source of special fissionable material in all peaceful activities"—that is "Completeness": the Additional Protocol provides complementary legal authority that strengthens the Agency's ability to detect undeclared nuclear material and activities. It is only for States with both a CSA and AP in force that the Agency is able to conclude that all nuclear material remains in peaceful activities in the State. And that is why the

M. Aparo (✉)
International Atomic Energy Agency, Vienna, Austria
e-mail: m.aparo@iaea.org



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additional protocol is vital in strengthening the verification regime, by providing us with additional information and broader access to sites and locations.

The work of our inspectors—backed by analysts and technical support staff in Vienna—continues every day across the world. Sustaining that global operation requires resources, commitment and capability. Here, I want to stress that it is our legal obligation to implement safeguards—it is not a matter of choice. Our legal obligations determine our workload, and our workload continues to increase while our budget broadly remains the same.

*Challenges*—While the core safeguards mission does not change, the world in which we operate does. When coupled with increasing demand on safeguards services, this means we need to adapt in order to sustain the credibility of the safeguards system.

Alongside the steadily rising number of nuclear facilities and locations outside facilities that are under safeguards—currently over 1300—in recent years we have also seen a significant growth in the number of Additional Protocols in force—around 40 in the past decade—to now stand at 134. As you are aware, the additional protocol gives the Agency broader access to information about all parts of a State's nuclear fuel cycle, including research and development activities, as well as the manufacturing and export of sensitive nuclear-related equipment and material.

The volume and diversity of safeguards-relevant information is growing rapidly. More Additional protocols in force means more Additional Protocol declarations to be checked. Open source information grows exponentially, thereby increasing the demands on analysts to keep pace and to identify the most relevant information.

The Agency now conducts more complicated verification activities than ever in the past, to keep pace with the nuclear fuel cycle developments of States under safeguards. For example, today there are a lot more spent fuel transfers to medium and long-term storage and more decommissioning of facilities than previously.

Globalization, new technology and modern communications have all made it possible to access technologies, materials and expertise that were previously not widely available. Technology that could be used for the development of nuclear weapons is no longer out of reach for a growing number of States.

And advancements in information technology have heightened cyber security threats to the protection of sensitive information that has been provided to the IAEA—in confidence—by Member States.

*Meeting the challenges*—So, how is the IAEA and more particularly the Department of Safeguards responding to the challenge of adapting to change in the context of rising demand and a tightly constrained budget? Let me set out some of the ways in which we are seeking to do so.

Let me start with State-level safeguards.

State-level safeguards approaches (SLAs) are a very important tool to improve the effectiveness of safeguards. They also enable the Agency to better cope with a fast changing environment because, unlike the Safeguards Criteria, they can respond to changes in State-specific factors, such as changes to a State's nuclear fuel cycle. In other words, the frequency and intensity of safeguards measures can be adjusted in line with changes to those factors. SLAs, developed based on detailed procedures and defined steps, also allow for a more consistent definition and prioritization of technical objectives.

As part of the Secretariat's ongoing dialogue with States on this matter, in July last year, the DG issued his report on 'Implementation of State-level safeguards approaches for States under integrated safeguards—experience gained and lessons learned'.

Moving forward, our immediate efforts are concentrating on ensuring that our SLA processes are indeed consistent and applied uniformly across all operations divisions. The Department is developing additional guidance and tools to support the work, and reviewing and updating the SLAs that have been developed so far. We are using a robust internal review process for this, ensuring safeguards approaches are objective and non-discriminatory. The current focus is on updating and refining the SLAs for States under integrated safeguards, so that our experience with these States can be improved over time.

The number of States with a comprehensive safeguards agreement for which an SLA has been developed has now reached 130. These 130 States hold 97% of all nuclear material (by significant quantity) under Agency safeguards in States with a comprehensive safeguards agreement. So you can see that we have made significant progress on this front and we will continue to develop and implement SLAs for all States, in accordance with the processes set out in the Supplementary Document presented to the IAEA Board of Governors in 2014.

The Safeguards Department's main product to the Board of Governors is our conclusions, which are contained in the annual Safeguards Implementation Report. These conclusions are the product of an internal process called State evaluation. State evaluation is the ongoing evaluation of all relevant information available to the Agency about a State and is aimed at assessing the consistency of that information in the context of a State's safeguards obligations. To be effective, we need the State evaluation process to be rigorous, with thorough analysis underpinning soundly-based and well documented results. One of the ways in which I have strengthened State evaluation is through the use of Peer Review Teams. These are proving extremely useful in making sure that State Evaluation Groups consistently use the best approaches and tools in preparing SERs and in drawing up Annual Implementations Plans.

All of this work in relation to SLAs has now been pulled together under a major Departmental project to ensure that SLAs all meet a high standard of quality and are implemented to the same standard.

The modernization of safeguards IT under the MOSAIC project has ensured that the Department's IT system supports all safeguards implementation processes well into the future. Through MOSAIC, new and improved IT applications are allowing for better planning, conducting, reporting, and quality assessment of safeguards activities. The Department has undertaken this upgrade using in-house expertise, but has relied heavily on extra-budgetary support from Member States. The entire upgrade was completed in May 2018—on schedule and within budget.

Another crucial benefit of the MOSAIC project was the increased ability to defend against cyber security threats that it delivered. Indeed, in recent times, the Department of Safeguards has taken a number of important steps to improve the cyber security of information in its possession. These steps include moving safeguards confidential system and files into a secure environment, raising staff awareness about cyber threats, and ensuring that we comply with international best practices in this area.

Environmental sampling and nuclear material analysis are crucial to effective verification. As capabilities in this area advance, the IAEA's analytical laboratories in Seibersdorf and the 22 other laboratories that comprise the Agency's Network of Analytical Laboratories will remain tightly coordinated. The Agency is examining ways of improving the timeliness of its analysis. The IAEA will also improve its quality control programme for the Network of Labs, in particular in the area of particle analysis.

The Agency is constantly working to ensure that it deploys equipment for measurement and containment techniques that inspectors find easy to use. Such equipment needs to be sufficiently rugged to be shipped around the world and flexible enough to be used in a number of different environments.

The Agency has expanded and enhanced it use of unattended monitoring systems and improved its corresponding capability to receive remote data transmission at Headquarters in Vienna. The use of remote data transmission enables greater verification efficiency by relieving inspectors of the task of collecting and reviewing data at facilities. It also allows early detection of any deterioration in system performance.

The Agency also now constantly monitors commercial technologies to identify and potentially exploit innovations that could enhance its capabilities. In November 2018, at the IAEA's quadrennial Safeguards Symposium, for example, the Agency looked at the possibilities offered by robotics and how different gamma imaging cameras might be utilised. The Agency is keen to find promising technologies for further testing and, if such tests are positive, move expeditiously to deploy them in the field.

At the diplomatic level, Member States increasingly want to better understand how safeguards are implemented and to receive new levels of communication and transparency from the Secretariat. We will maintain that active dialogue with our Member States through bilateral discussions, technical meetings and formal reports to the Board of Governors.

*Iran*—Turning now to the Joint Comprehensive Plan of Action—JCPOA or "Iran nuclear deal"—which has posed particular challenges for the IAEA: in terms both of overall effort and in particular technical aspects.

Clearly, it is a gain for verification. The combination of a Comprehensive Safeguards Agreement, Additional Protocol and further transparency measures itemised in the deal represents the most robust overall verification system applied in the world today. And Iran's nuclear-related commitments under the deal have resulted in a significant reduction in Iran's declared nuclear activities and major constraints on those activities that Iran is allowed to maintain.

While the IAEA played a key role before, during and after the negotiation of the JCPOA, it is not a party to the Agreement. Nor is it for the IAEA to determine whether Iran is in compliance. We simply report the facts to our Board of Governors and to the UN Security Council.

In order to verify and monitor Iran's implementation of its nuclear-related commitments under the JCPOA our inspectors are on the ground 24/7. They now spend around 3000 days in the field in Iran each year, twice as many as before the deal took effect. They have taken hundreds of environmental samples and placed around 2000 tamper-proof seals on nuclear material and equipment. The Agency has collected and analysed hundreds of thousands of images captured by our sophisticated surveillance cameras along with several million pieces of open-source information. Furthermore, all of our activities are supported by state-of-the-art technology, including systems that collect and process data. Added to which we have access to more locations under the Additional Protocol, which enables us to learn more about Iran's nuclear programme overall.

Many of the things the Agency was requested to do under the JCPOA (and the Joint Plan of Action before it)—required it to develop new, robust approaches and ways of working—even to develop new equipment—and to do so inside a very short timeframe. In such cases there were no "baseline" documents to consult, and no precedent to help us.

As all of us are keenly aware, the future of the Iran deal is uncertain. Iran has reduced a number of its commitments. Nevertheless, the Agency's verification and monitoring system in Iran remains intact and we will continue to report the reality on the ground for as long as we are required to do so.

*DPRK*—It is over a decade since IAEA inspectors were required to leave North Korea. Since then, the Agency has not been able to carry out any verification activities in the country. However, the Agency continues to monitor the DPRK's nuclear programme and evaluate all safeguards-relevant information available to it, including open source information and satellite imagery.

In the past 10 years, the DPRK's nuclear programme has significantly expanded. It has started uranium enrichment, built a light water reactor and restarted all the nuclear facilities in Yongbyon, including the 5 MW(e) reactor and reprocessing plant. However, without access, the Agency cannot confirm the nature and purpose of the activities I just described. Since 2009, the DPRK has announced that it has conducted five nuclear tests, in addition to the one announced in 2006.

In 2017, the Agency created an Executive Group and Agency Team dedicated specifically to the DPRK. This team has increased the monitoring of the DPRK's nuclear programme through more frequent collection of satellite imagery. It has also enhanced the Agency's readiness to promptly undertake any verification it may be requested to conduct in the DPRK if a political agreement is reached among countries concerned. Subject to the approval of our Board of Governors, we could respond within weeks to any request to send inspectors back to the DPRK.

*Conclusion*—By successfully addressing the challenges that I have identified today, we can ensure that the IAEA continues as a modern, highly productive and lean verification organization. Inside the Safeguards Department we will continue to improve our processes to ensure delivery of desired outcomes; maximising collaboration through teamwork within the Department; and ensuring an efficient distribution of resources. Such enhancements are vital if the Agency is to bridge the gap between demand and resources, and demonstrate to Member States that it is using their resources wisely and effectively.

The challenges to the safeguards system are more profound and varied today than they have ever been. To succeed, the IAEA will need to be able to respond to the unexpected, while strengthening the credibility of the safeguards conclusions it draws. I am confident that working together with Member States and the wider safeguards community, we can meet those challenges and make the world a safer place for future generations.

# Chapter 12
# Science and Technology for Putting an End to Nuclear Explosions

**Tammy Taylor**

Dear Distinguished Ladies and Gentlemen,

Thank you for inviting me to be here with you for the XXI Eduardo Amaldi Conference in the beautiful facilities of the Accademia Nazionale Dei Lincei. The Comprehensive Nuclear-Test-Ban Treaty, the CTBT, was designed to establish a mechanism to monitor and verify the cessation of all nuclear explosions—to help humanity put an end to the grave consequences of nuclear explosions. As the Director of the International Data Center Division of the CTBT Organization (CTBTO), or the Provisional Technical Secretariat (PTS) as it is commonly referred to, I'm delighted and honoured to engage with this scientifically and politically elite group of experts to elaborate on a few of the CTBTO's most significant science and technology pursuits in the context of putting an end to nuclear explosions.

The nuclear test ban became comprehensive more than three decades after the adoption of the 1963 Partial Test Ban Treaty, which had banned nuclear weapons tests in the atmosphere, in outer space and underwater. In the 1990s, the global community sought to achieve the discontinuance of all test explosions in all environments, including underground for all time. The CTBT opened for signature and ratification 23 years ago. Annex II of the treaty specifies the signature and ratification by a mandated set of 44 nations who all possessed nuclear reactors in 1995. Eight nations remain of the 44 mandated who must either ratify or sign and ratify the treaty to enter into force. Currently the treaty has 184 signatories and 168 ratifications.

The CTBT is a treaty rooted in the recognition that the cessation of all nuclear explosions is a requisite to nuclear disarmament and non-proliferation. In the preparations for the 2020 NPT Review Conference the international community could chose to concentrate their efforts on issues of broad common agreement, such as the CTBT. As the statements of support towards the CTBT showed in the May 2019 NPT PrepCom in New York, there are shared beliefs and principles about a large set

T. Taylor (✉)
Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
e-mail: tammy.taylor@ctbto.org



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of security and humanitarian consequences of nuclear testing and about the necessity of preventing their use.

The CTBT is an instrument supported by a technology-led verification regime. Scientific technologies are essential for verification of nuclear non-proliferation and disarmament. The CTBT Verification Regime Elements established in Article IV of the treaty are as follows:

- *The International Monitoring System* (IMS) of 321 stations that include seismic, hydroacoustic, infrasound, radionuclide components, the International Data Centre (IDC), and the Global Communications Infrastructure.
- *Consultation and Clarification* to allow State Signatories the right to seek clarification on matters that indicate the possibility of non-compliance with the Treaty following entry-into-force.
- *On-Site Inspection* to provide for the ability to conduct on-site verification activities if a nuclear detonation is suspected by States Signatories. The on-site inspection regime is designed to confirm on the ground whether a nuclear explosion has taken place. The PTS can build the capacity to perform these on-site inspections and test our preparedness, but no on-site inspection will r take place until the treaty has entered into force.
- And finally, *Confidence Building Measures* intended to strengthen CTBTO capabilities, prevent misinterpretations and allow for better calibration of the stations of the IMS.

The IMS will ultimately be made up of 337 facilities, 321 of which are monitoring facilities and 16 radionuclide laboratories. These facilities are located around our earth and they collect and transmit data to the IDC for processing and analysis. The IMS is more than 91% complete at this time with 44 of 50 primary seismic stations, 108 of 120 auxiliary seismic stations, 11 of 11 hydro-acoustic stations, 51 of 60 infrasound stations and 71 of 80 particulate radionuclide stations certified. Forty of the radionuclide stations will have noble gas detection capabilities once the IMS is fully constructed. Since 2012, 25 noble gas systems have come online, been certified and are sending data to the IDC. Thirteen of sixteen radionuclide labs are currently operational and certified.

In summary, today the IMS is comprised of 297 certified facilities, including radionuclide laboratories. There are nine installed facilities that are not yet certified for operations, six facilities under construction, and 25 planned facilities for the total of 337 IMS facilities. The precise location of each facility was envisioned by the treaty negotiators between 1993 and 1996. The locations were selected based on optimal global coverage. Scientific communities from around the world were heavily involved in site selection optimization. Figure 12.1 is a current map of the IMS.

The charge of the PTS in the context of the data generated from the monitoring facilities is to receive, collect, process, analyse, report on and archive the data from the IMS, and to provide States Parties with open, equal, timely and convenient access to all IMS data, raw or processed, and all IDC products. The PTS also provides technical assistance to individual States Parties whenever this assistance is requested.

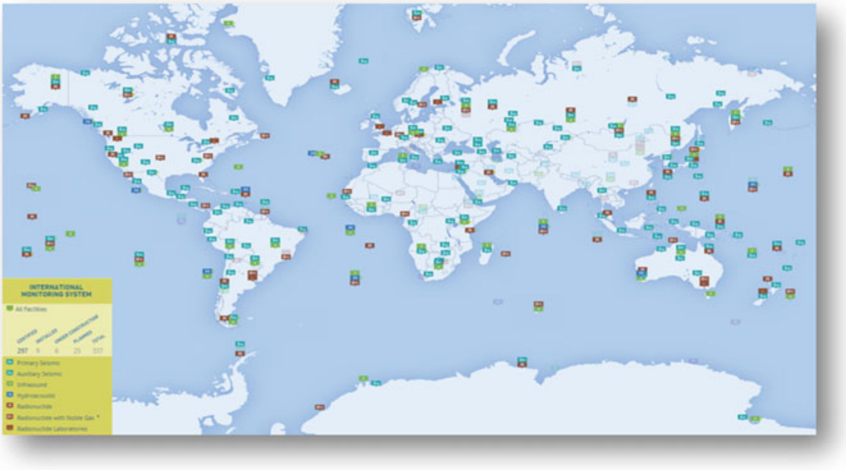


**Fig. 12.1** Map of the International Monitoring System (IMS)

To accomplish the above, the PTS established the Global Communications Infrastructure (GCI) to provide a massive communications system, which utilizes nine geostationary satellites to bring data from the IMS facilities to the PTS in Vienna, Austria. The communications network also transmits data to the National Data Centres (NDCs) operated by the States Signatories. This allows the States Signatories to draw an independent conclusion on the nature of events picked up by the system and ultimately determine whether it was a nuclear explosion. Approximately 14 terabytes of data per year is transmitted through GCI making the CTBT second to none when it comes to monitoring and understanding our planet. This communications infrastructure is key to the operation and security of data from the IMS. The current GCI satellite coverage is summarized in Fig. 12.2. The GCI is in its third 10-year contract (GCI III). GCI III is operated by Hughes Network Services.

I just mentioned the four technologies that allow the CTBT to detect nuclear explosions—seismic, hydroacoustic, infrasound, and radiation detection. Tens of thousands of naturally occurring events affect our planet each day. To date the PTS has characterized nearly 600,000 events. Figure 12.3 provides a summary of all PTS relevant nuclear detonations between 2000 and 2018.

With that as an overview to establish some practical and political background of common interests, let me narrow in on the operations of the IMS led by the IDC Division of the PTS. I would like to share two specific examples of CTBT global contributions that illuminate our science-based technology capabilities. After that, I will summarize one example of science and technology needs required to continue to advance our progress in nuclear event detection.

I have the honour to lead the IDC in Vienna as Director where about 100 analysts, scientists, engineers, specialists, technicians, administrators and leaders navigate the IMS data to monitor for nuclear explosions and report on all relevant energetic events

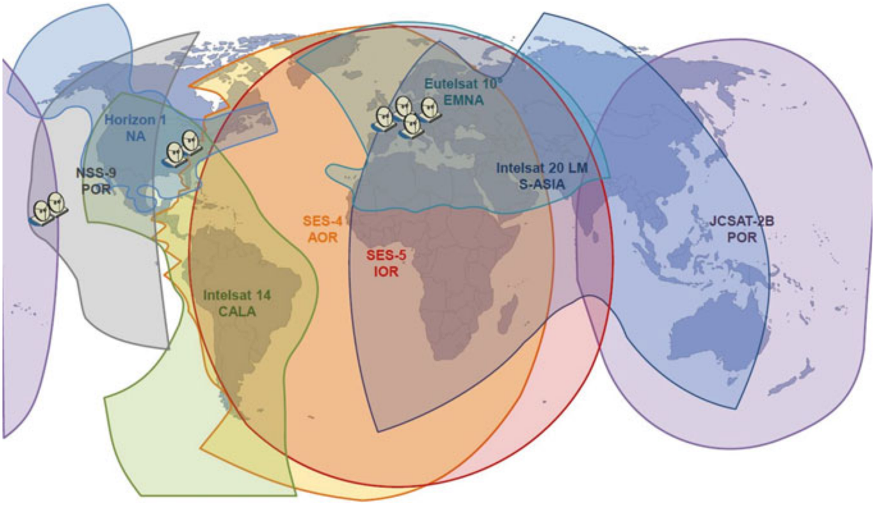


**Fig. 12.2** GCI III global satellite coverage

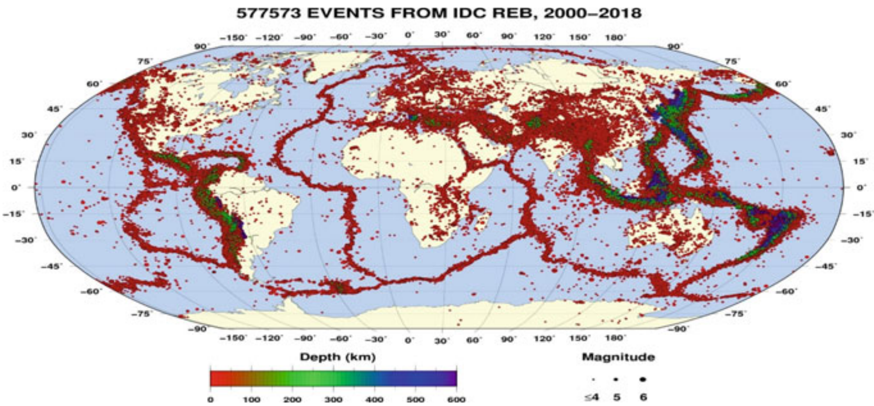


**Fig. 12.3** Events totalling 577,573 located by the IDC between 2000 and 2018

to our States Signatories. The IDC staff also steward capacity building programs designed to strengthen national and regional capacity to promote understanding of these unique data and apply them for verification purposes, disaster management capabilities and sustainable development.

The first global contribution highlight I offer is the PTS leadership provided following the Japan earthquake of 11 March 2011, which resulted in a massive tsunami that led to the Fukushima Daiichi Nuclear Power Plant accident. The earthquake was a magnitude 9 event and generated 9800 aftershocks. Figure 12.4 shows the event (represented by the black star) and the 9800 aftershocks. Infrasound signals generated in Japan were seen at station I44RU in Kamchatka. Figure 12.5 illustrates

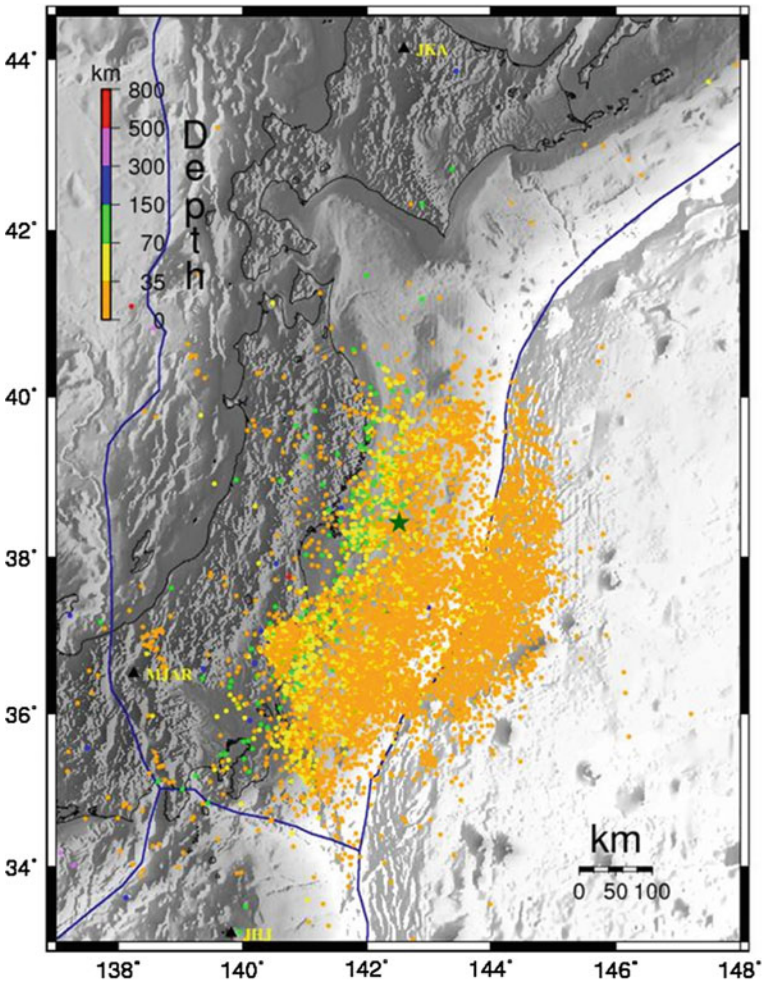


**Fig. 12.4** Japan Earthquake 11 March 2011; magnitude 9 earthquake and 9800 aftershocks

the infrasound signatures. Importantly, radioactivity released from the Fukushima Daiichi Nuclear Power Plant was detected worldwide by the IMS and then characterized by IDC analysts. Figures 12.6 and 12.7 show the atmospheric dispersion of a standard radioactivity release from the accident and the specific radionuclide detections at the closest IMS station, respectively.

The PTS cooperation in the global response to the Fukushima accident was notable. We were the only organization in the world to possess the ability to measure radionuclides continuously at the global scale. Our results were used by States Signatories as well as UN organizations to prioritize response activities and understand potential public health consequences.

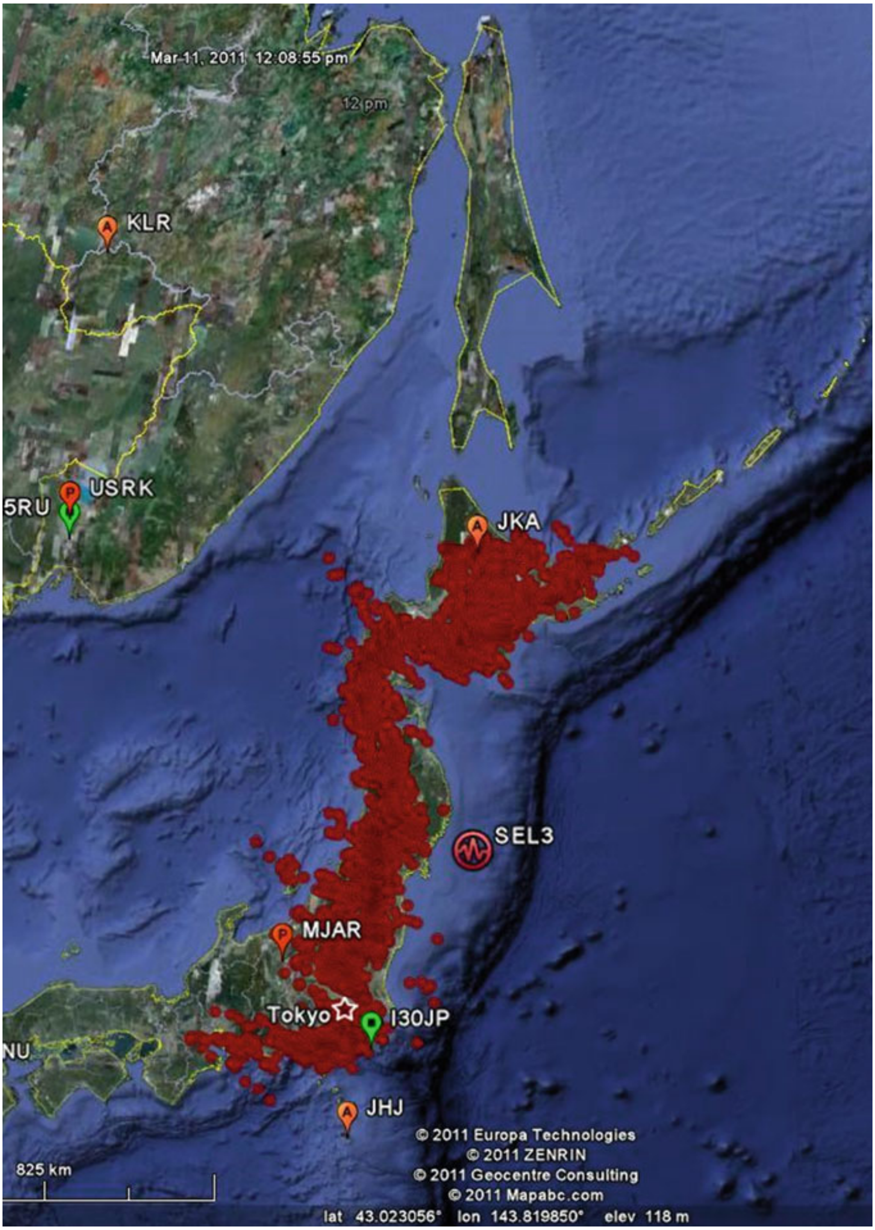


**Fig. 12.5** Infrasound signals generated in Japan on 11 March 2011 by earthquakes and tsunami as seen at I44RU (Kamchatka)

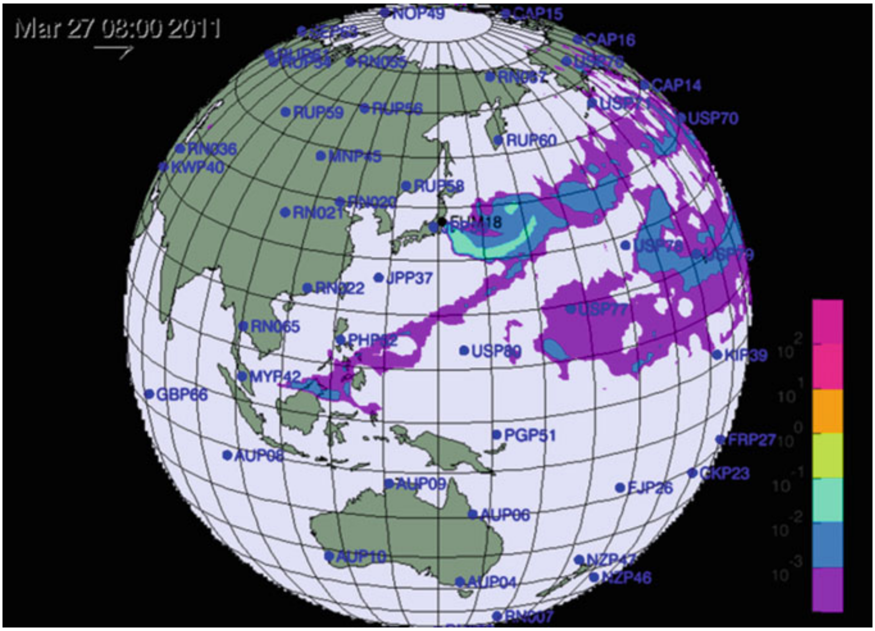


**Fig. 12.6** An illustration of atmospheric transport modelling that portrays release of radiation from the Fukushima Daiichi Nuclear Power Plant accident

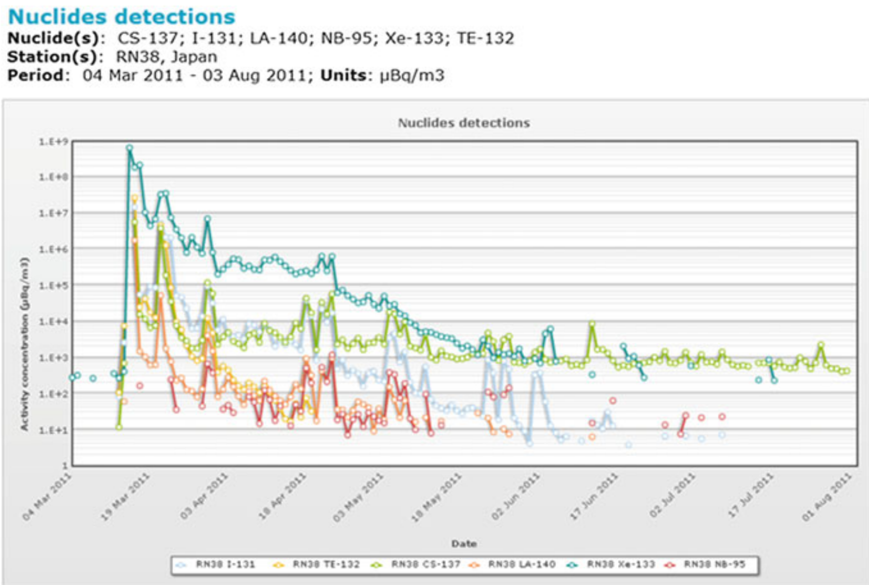


**Fig. 12.7** Nuclide detections measured over time following the Fukushima accident measured from radionuclide station RN38 located in Japan

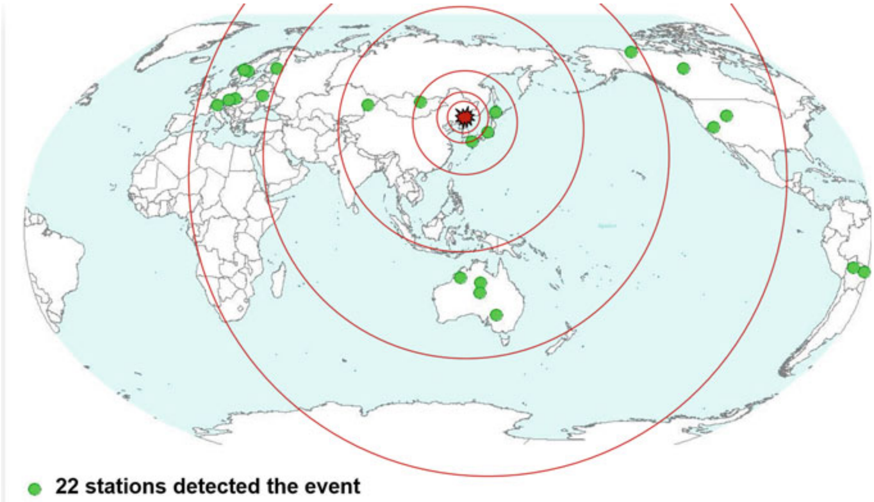


**Fig. 12.8** DPRK test 1 conducted on 9 October, 2006 as detected by 22 IMS stations globally


**Fig. 12.9** Historical seismicity in the region of DPRK test site

The second highlight that illustrates the significance of PTS capabilities is the significant analysis of the Nuclear Testing Program carried out by the Democratic People's Republic of Korea (DPRK), which has announced a total of six nuclear tests. The first test was conducted on 9 October 2006. Twenty-two IMS stations detected the test as illustrated in Fig. 12.8. History had provided a glimpse into the seismicity of the region near the test site. On 16 April 2002 an earthquake was characterized in the region. This earthquake provided strong comparison waveform data to evaluate against the test of 9 October 2006. Figure 12.9 summarizes the proximity of the earthquake location and the test event location.

Following the event, IDC analysts began examining the data from IMS monitoring stations. Figure 12.10 provides a tutorial of the distinction between an explosion, which generates a spherically symmetric propagation of shock waves (P waves),

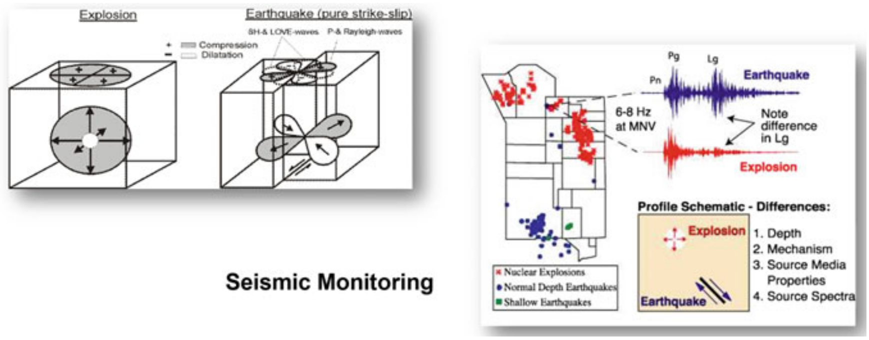


**Fig. 12.10** Data characteristics for explosion versus earthquake

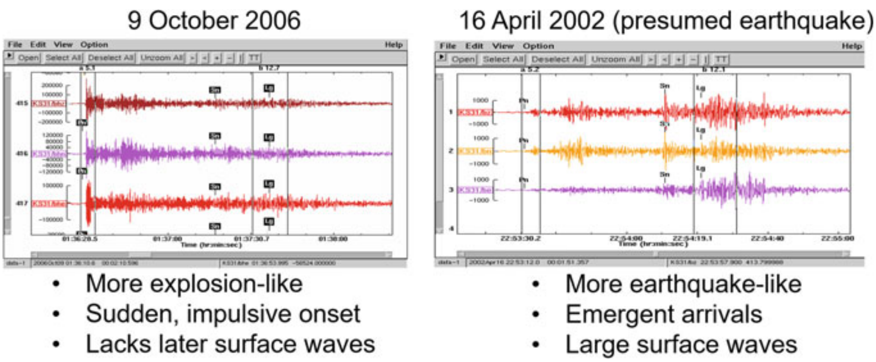


**Fig. 12.11** Comparison of data characteristics between an explosion and an earthquake in the region of the DPRK test site

and an earthquake, which generates both P- and shear waves owing to a substantially more complex double-couple mechanism. The resultant distinction between the seismograms is illustrated in the right half of Fig. 12.10. The seismogram for the earthquake is illustrated in blue and shows propagation of large surface waves as well as emergent arrivals. The seismogram for the explosion is illustrated in red and shows a sudden, impulsive onset, but lacks the later surface wave characteristics. Figure 12.11 illustrates the seismogram results for the 9 October 2006 nuclear test in comparison to the 16 April 2002 presumed earthquake.

IDC software automatically processes metadata that arrives from monitoring stations. The primary purpose of the software is to help eliminate events that are clearly of natural origin. Key screening criteria are applied. One important criterion is a comparison between surface wave magnitude (Ms), waves that travel along the surface of the earth, and body wave magnitude (mb), waves that travels down into the earth's core. Ms and mb are both measures of the amount of energy released and are recorded as amplitude of wavelength, in other words, the amplitude of the waveform signal.

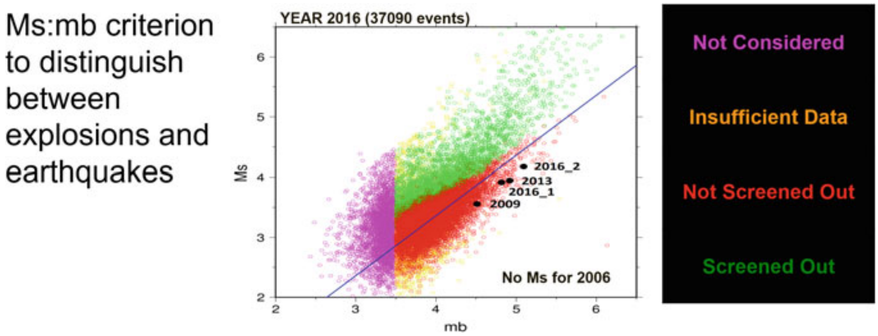


**Fig. 12.12** Analysis characteristic criteria to distinguish between explosions and earthquakes

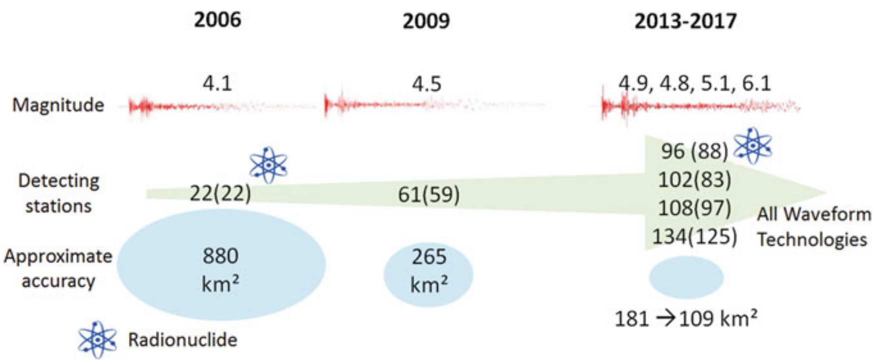


**Fig. 12.13** Summary overview of all DPRK seismic events

As a result of the difference between Ms and mb, explosion signals show an mb/Ms ratio larger than that for earthquakes. Figure 12.12 illustrates a large data set from 2016 comparing four different sets of data categories stemming from the data characteristics.

To conclude the highlights of significant global PTS contributions, please see Fig. 12.13, which represents a summary of the six DPRK tests. Note that two of the tests generated radionuclide (specifically radioxenon) detections—the first DPRK test in 2006 and the 2013 third DPRK test. I'll speak more about these radioxenon detections as I begin discussing our science and technology needs example.

Before I transition to this example however, I would like to emphasize the CTBTO's readiness to make available our assets and expertise to contribute to DPRK denuclearization should the opportunity present itself. The three main areas the PTS could contribute to are:

- test site closure verification support activities,
- verification of a nuclear test moratorium

- and signature and ratification of the CTBT by the DPRK, which is one of the remaining 8 States required to adhere to the treaty.

Through any of these three areas, the CTBTO and its verification regime have the clear potential to contribute to the denuclearization of the DPRK. Other massive responsibilities such as removal of fissionable material and dismantlement of an actual nuclear arsenal fall well outside the mandate of the CTBT and the expertise of PTS staff capabilities.

The area of science and technology need that I would like to highlight for you today is associated with the noble gas technology. Radiation-based technologies provide rich research and development collaboration opportunities with scientists around the world. The two CTBTO radiation technologies, radioactive particle and noble gas detection, are the means by which we confirm that an event is verifiably a nuclear one. We are constantly looking for the presence of one or more of 87 anthropogenic radionuclides. Exposed to prevailing winds, radiation is dispersed in the atmosphere and may, after a certain period of time, be detected thousands of kilometers away from an explosion site. The objective of the CTBTO's radionuclide monitoring network is to detect residual radiation even if only in minuscule amounts. Our network of laboratories supports the radionuclides stations around the world.

Following the first DPRK test, PTS researchers carefully reviewed xenon data, specifically $^{133}$Xe, according to meteorological predictions that forecasted where the air mass originating from the test site would be moving around the earth. The researchers narrowed in on the Yellowknife, Canada (CAX16) noble gas equipped radionuclide station. This station was impacted by noble gas background concentrations generated from the Chalk River Laboratories (CRL) in Canada. In October of 2006 a xenon emission became obvious that was not related to CRL. Background xenon was at a low point during this time period and atmospheric transport modelling, assuming an emission of 1PBq of $^{133}$Xe from the 9 October 2006 nuclear test corresponded well with the detection observation. The first IMS radioxenon detection from a nuclear detonation was verifiably identified by the IDC analysis.

The only other strong evidence of IMS radioxenon detection of a nuclear test came following the 12 February 2013 DPRK third nuclear test. Stations RN38 (Takasaki, Japan) and RN58 (Ussuriysk, Russia) showed spikes in radioxenon concentrations more than 50 days after 12 February 2013. The nuclear test became evident as the source of these detections by a combination of estimating the origin time of the fission event based on the observed $^{131m}$Xe/$^{133}$Xe activity ratios and atmospheric transport modelling scenarios which suggest strongly that delayed radioxenon emissions originating from the DPRK test site were captured by the noble gas systems at two IMS stations.

In both the 2006 and 2013 xenon detection evidence, background concentrations of radioxenon emissions at the three IMS stations were at abnormal concentrations but still less than many other observed spikes of radioxenon. The global inventories of xenon emissions around the world is unfortunately resulting in many detections every day including one or two at abnormal concentrations every day. This causes a background noise that doesn't always make it possible or easy to characterize

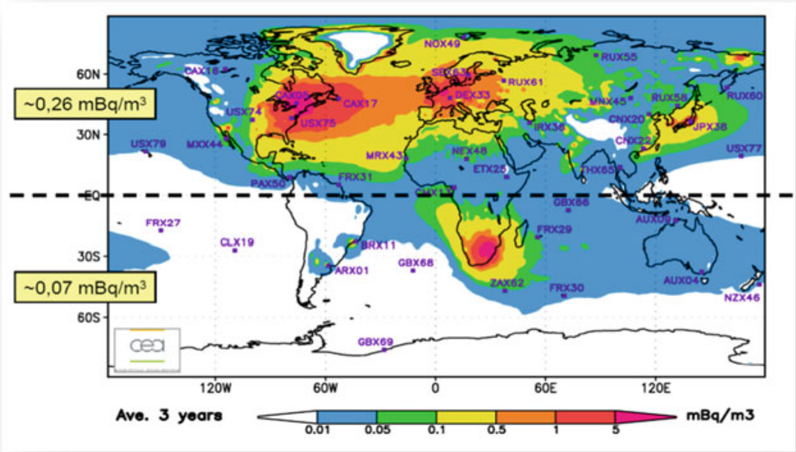


Fig. 12.14 Average background of Xe-133 Image provided by G. Le Petit, CEA, France

**Fig. 12.15.** "Hit rate" above detection limit Image provided by H. Miley and P. Eslinger, Pacific Northwest National Laboratory, USA

radioxenon origins. Essentially, the radioxenon that could be released from a nuclear test may be masked by the abundance of radioxenon present in the background. With sufficient knowledge and sophisticated methods nuclear test signatures may be unmasked and its source identified. Figures 12.14 and 12.15 provide a summary of the geographically varying abundance of radioxenon in the environment as a consequence of primarily isotope production and nuclear power plant operations.

The next big science and technology improvements for the PTS require methods to extract possible nuclear detonation signatures as unique against the interfering

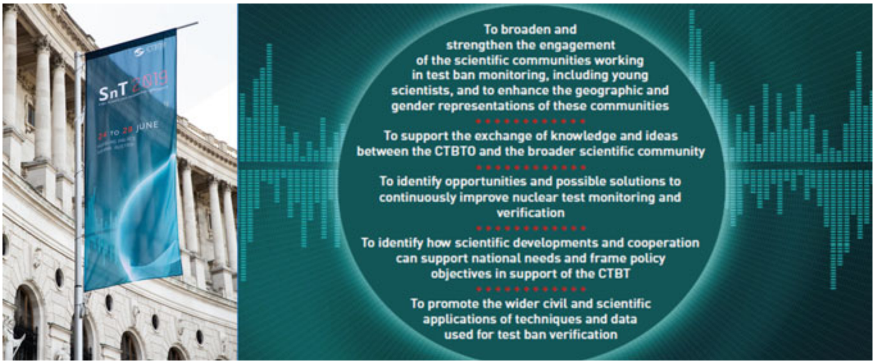


**Fig. 12.16** SnT19 goals

radioxenon background so that they are visible for verification activities. Characterizing sources to understand source-receptor relationships, conducting source receptor experiments, comparing isotopic ratios (i.e., comparing $^{135}$Xe/$^{133}$Xe to $^{133m}$/$^{131m}$Xe), and confirming when multiple samples catch the same plume will allow the science to advance to a point where radioxenon signals possibly indicating a nuclear explosion could be distinguishable in a high radioxenon background environment. As you will see in my summary of the CTBTO Science and Technology 2019 Conference below, scientists are already making progress towards this goal.

I believe the CTBTO continue to exist as we walk towards entry-into-force. As we continue on our journey, we must become more efficient, effective, and sustainable. One way we look to the future is every two years we host a CTBTO Science and Technology (SnT) Conference. In fact, just this past June, SnT19 was hosted in Vienna. This extraordinary full week experience features the scientific and technical magnitude of the CTBT verification regime and welcomes collaboration to envision improving our science and technology base through experts working in test ban treaty monitoring. SnT events foster partnerships and discussions with the scientific communities in support of the CTBT and related national needs. SnT19 accomplish this while highlighting the accomplishments and accepting input from young scientists and enhancing geographic and gender representation. 1200 scientists, experts, practitioners, and youth from 100 countries attended the 2019 conference. Figure 12.16 provides an overview of the SnT19 goals.

I want to share just a few highlights from the SnT conference hosted this past June in Vienna at the Hofburg Palace.

- Numerous independent analysis of the DPRK announced nuclear test on 3 September 2017 demonstrated common understanding and raised confidence in IMS monitoring capabilities.
- Scientific experts are still considering data to search for radioxenon signals in background noise to associate radioxenon emissions with all announced nuclear tests of the DPRK.

- Progress is being made towards preserving and making available for research digitized data of historic nuclear explosions.
- Measurement campaigns at historic test sites confirmed the correlation of Ar37 and Ar39.
- The application of gamma spatial imaging is relevant in the context of an on-site inspection.
- Advancement in hydro-acoustic signal analysis and interpretation is now allowing researchers to identify direct and several reflected paths on various bathymetric structures and perform event location.
- Synergy between atmospheric observation and modelling with infrasound data demonstrates the strong link between improvement in middle atmosphere weather models and accurate infrasound analysis with signal interpretation.
- NET-VISA was successfully implemented in CTBTO operations for seismic network processing associated with event building.
- Earthquake detections by IMS stations supported advances in earth sciences on a global, regional and local scale with a key benefit resulting in better location accuracy for CTBT monitoring.
- Machine learning is quickly becoming a useful tool for significant improvements in the fast travel time calculation in various 3D earth models.
- New methods of event location based on waveform cross correlation (WCC) are able to improve the accuracy of absolute location by two orders of magnitude.
- Waveform correlation processing methods were demonstrated on aftershock sequences to be effective for operational monitoring systems with a sparse global network.

It was highlighted in multiple sessions and panels that artificial intelligence and machine learning is needed for cybersecurity advances and the management and subsequent use of our IMS data. Cyber security threats are coming faster and are becoming increasingly too complex for humans to respond to. By the time a threat has been noted, response is too late. The continuous increase in computational power and more sophisticated modeling is generating tremendous amounts of data. This in turn is beginning to lead to the accelerated development of artificial intelligence to deal with this data. There is already a large amount of data available to the CTBTO for more enhanced atmospheric and oceanic transport modeling.

Several SnT19 presentations highlighted the challenge of sustaining operational success of the IMS as focus shifts from network growth to sustainment, where the budget can no longer buy the same performance improvements. As the IMS reaches completion of the network, we need predictive maintenance approaches with fast issue identification to help support more effective resource allocation.

SnT19 hosted two language panels, one in French and one in Spanish, which highlighted the link between multilingualism and multi-lateralism, particularly in the context of a highly technical treaty and an international organization with state signatory stakeholders. The relevance of science and diplomacy approaches was undeniable and cooperation outcomes were substantially beyond what we could have accomplished in English alone.

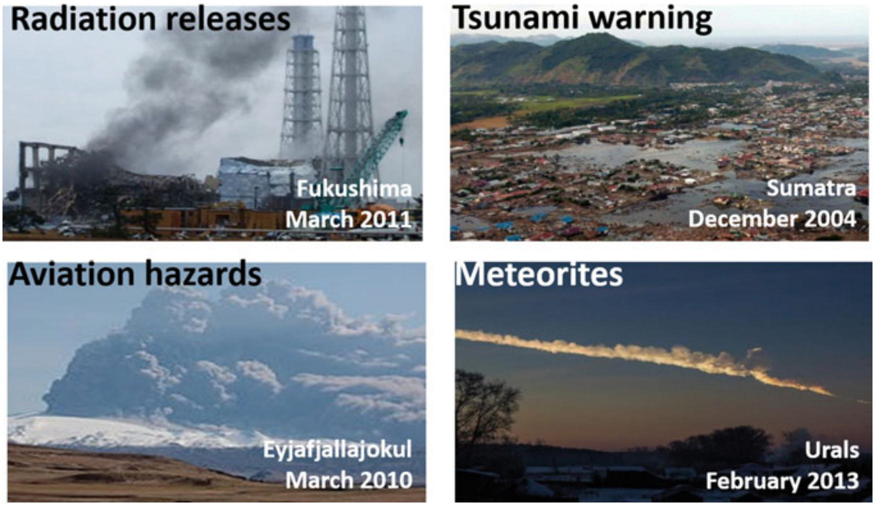


**Fig. 12.17** Civil and scientific applications of IMS data

The necessity of inclusion and development of expertise through capacity-building programs and scientific and civil applications is a continuous recommendation from the global community. Let me stay with this theme of a SnT19 highlights in the context of the importance of civil and scientific applications. In order to strengthen the support for the CTBT around the world, it is important to emphasize potential civil uses and benefits of the IMS data. As a scientist, I must draw your attention to the enormous potential of this data in terms of better understanding our planet.

Civil applications include tsunamis, volcanoes and earthquakes. Disaster risk mitigation, climate change, and the study of marine life are some of the scientific applications of these technologies. We collaborate with scientists who follow the migration of marine mammals with our hydro-acoustic technology, for example. At SnT 19, scientists suggested use of our data for monitoring of air pollution and research related to biodiversity changes. Figure 12.17 summarizes some of the applications and/or potential applications of IMS data to civil applications.

If you or anyone in your institution is interested in our IMS data for your own research purposes, please submit a proposal through our voluntary data exploitation center or vDEC. The process is fully described in our homepage at ctbto.org and the data you are approved to use for research purposes will be delivered to you months after our States signatories receive it. Historical data can be delivered following approval of your proposal.

I would like to close with two areas of best practice that I've seen demonstrated at CTBTO that I think are practical for all of us in our modern workplace. Global policy successes and science and technology advances are yearning for the benefits derived from increased participation by women and youth in STEM disciplines. This is nothing new. We have been talking about this for ages. We must find innovative and attractive ways to make these advances a reality. UN organizations are emphasizing gender parity striving for a 50/50 women men staff ratio by 2030. The CTBTO senior leadership team has achieved gender balance with three women directors alongside three men directors. We are working diligently to advance gender balance in our technical areas as well.

CTBTO has sought to engage the views of young women and men determined to promote the CTBT and its verification regime. Created in 2016, the CTBTO Youth Group, the CYG, now has over 700 members from more than 100 countries. With generous financial support from the European Union, CYG members have participated in and contributed to major global and regional gatherings, including the CTBTO youth conferences held in Moscow and Astana in 2017 and 2018 respectively. The growing role of the CYG in advancing the ratification of the treaty shows how youth can act to change minds in countries that have not yet ratified. We increasingly find that young experts can reach countries and regions through their networks where other methods of advocacy have been ineffective. I invite the younger experts in the audience to join the CYG and discover fascinating technologies behind the CTBT verification.

With such considerations in mind, I truly appreciate the opportunity to address you as an expert group. I hope that together we will explore avenues towards increased exchanges or collaboration wherever possible. For my part, I thank you for inviting me to be here with you.

# Chapter 13
# Challenges and Opportunities in Scientific and Technological Support for Monitoring in the Non-proliferation Regime

**Jill Hruby**

This paper focuses largely on the challenges and opportunities for monitoring declared and undeclared facilities for other than peaceful uses. There are five technology areas for monitoring that will be addressed: (1) wide area environmental sampling, (2) open-source satellite imagery, (3) civil society reporting, (4) antineutrino detection, and (5) data fusion and automation to combine information from multiple sources.

Although not covered in this paper, another challenging area for Non-Proliferation Treaty (NPT) monitoring and verification is nuclear weapons dismantlement. This topic is being addressed by the public-private partnership between the U.S. Department of State and the Nuclear Threat Initiative called the International Partnership for Nuclear Disarmament Verification. Monitoring nuclear weapons dismantlement is technically very challenging and there is no silver bullet, but through this effort progress is being made.

*Wide Area Environmental Sampling*—Techniques for wide area environmental sampling include collection and analysis of atmospheric gases, atmospheric particulates, aquatic materials, vegetation, sediments and soils, and/or fauna. Historically environmental sampling has been deemed too expensive for practical use by the IAEA.

Of the possible wide area sampling techniques, atmospheric sampling has long been thought to be the most effective. Relevant nuclear signatures include Krypton-85 gas as a by-product of Plutonium reprocessing, and Uranyl Fluoride ($UO_2F_2$) aerosol from the interaction of leaked Uranium Hexafluoride ($UF_6$) and the air during Uranium enrichment. Reported challenges for atmospheric monitoring include[1]: the high

[1] Wogman [1] and STR-341 from 1995 and re-visit in 2010.

J. Hruby (✉)
Nuclear Threat Initiative, Washington, DC, USA
e-mail: jillhruby@gmail.com



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cost of a well populated sampling grid; the difficulty in detecting changes in Krypton-85 above baseline even with modeling due to the significant increase in background levels from the growing number of declared reprocessing programs, especially in the Northern Hemisphere[2]; and the sparsity of Uranyl Fluoride generation when improved filtering technologies are incorporated into enrichment plants.

However, there are some important opportunities in atmospheric environmental sampling. One particularly promising area is the use of drones or mobile platforms instead of a larger number of stationary sampling stations. Mobile platforms with miniaturized sensors, real-time data processing, and increasingly sophisticated models provide an opportunity to collect data at different locations with one or a few sampling systems, each responsible for covering numerous grid points. Additionally, the data could be used to optimize sampling locations especially for undeclared facilities or perhaps trigger additional types of sensors to be deployed. Cost savings could come from not having a fixed set of sampling locations, processing fewer samples, and having less labor-intensive analysis.

In addition to drones or mobile platforms, new detection and analyses techniques have also been advancing including especially laser spectroscopy.[3] Promising work has been done to accurately detect small amounts of Uranyl Fluoride using ultrafast laser filament-induced fluorescence spectroscopy, but not yet solving the cost issue. Techniques like this could become less expensive but also could be selectively used if triggered by mobile platforms, satellite imaging, or civil society reporting.

Additionally, there was work done in the early 2000s in the Central Asia Republics jointly with Sandia Labs,[4] and a case made by researchers at Idaho National Lab in 2013[5] that suggest aquatic monitoring approaches are worthy of consideration.

The increased sophistication of low-cost small sensors that could be scattered over wide areas with the ability to self-report also represent new opportunities. These sensors would not necessarily be atmospheric samplers, but could be radiation, acoustic, metrological, or other types of sensors that provide triggering data for other monitors, input to models, or corroborative information.

*Open-Source Satellite Imagery*—The revolution in commercial satellite imaging has provided an incredible boost to nonproliferation monitoring and more opportunities are coming at a rapid pace.

Trends in commercial satellites include larger constellations of smaller satellites with medium to high resolution that image the earth more frequently, and some satellites with very high resolution (less than 50 cm) that can stare at specific areas. As an example, Planet Labs has a constellation of 150 satellites in orbit. Their constellation allows line scanning of the entire earth every day with three-meter resolution, and the ability to monitor an area twice a day at 72-cm resolution. Both capabilities have at least 5 years of archived data for comparison.

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[2] Schoppner et al. [2].

[3] Skrodzki et al. [3].

[4] Passell, H. D. et al., "The Navurz Project: Cooperative, transboundary monitoring, data sharing and modeling of water resources in Central Asia" SAND2006-6673.

[5] Schanfein [4].

New active sensor systems like synthetic aperture radar[6] and video imaging allow vehicle movement, among other things, to be tracked. In 2018, the British company Earth-i released the first full-color video of earth from space taken by a commercial satellite. The views include airplanes in motion at Dubai international airport, cars driving in Argentina, and ships leaving port in Norway. Videos like these allow digital surface models to be developed and are useful for urban and remote sites with varied terrain to support inspection activities and to assist in characterizing unknown buildings.

Other new analysis approaches like hyperspectral imaging[7] can amplify the usefulness of satellite images. Hyperspectral imaging provides the ability to remotely discriminate between elements. European Space Agency's Sentinel-2 satellite now has 12 spectral bands available. Hyperspectral imaging may be particularly useful to identify conversion facilities as well as monitor reprocessing facilities.

New data fusion techniques that combine information from multiple satellites having different sensor suites[8] is also undergoing revolution. For example, the commercial company Palantir provides sophisticated data fusion services.

Overall, it seems that open source satellite imagery will continue to become more available and less expensive with the ability to get higher resolution images multiple times a day. Video images are also expected to become widely available as is hyperspectral data. Perhaps the largest issue for the nonproliferation community will keeping up with what is available and using it effectively. Caution is needed in using imagery by itself and can lead to conclusions that are not always accurate without additional information or knowledge.

*Civil Society Reporting*—The phrase civil society reporting is used here to mean engaging volunteers in monitoring, and specifically radiation monitoring in the cases discussed. In general, civil society reporting has been considered for emergency response or incident reporting, however, the use for NPT monitoring could prove promising. As one of the longest and most avid supporters of civil society reporting, Rose Gottemoeller has said "Not for every measure or every treaty would it be appropriate to have citizen volunteers involved. But I think, nevertheless, that in certain settings it could be quite useful to draw them in. And, in certain settings, indeed, dispersed sensing mechanisms on a number of mobile platforms could make a difference to how we understand deployment patterns in the future."[9]

There are three specific areas of interest to monitoring in the NPT regime, none ready for formal application, but illustrative of possibilities: one is people volunteering to use radiation detectors to record and report doses, two is people using their cell phones as detectors with an affiliated app to record and report radiation doses, and third is social media as a mechanism for reporting and/or obtaining relevant information. Radiation monitoring by volunteers combined with other information could

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[6]"Emerging Satellites for Non-Proliferation and Disarmament Verification," Vienna Center for Disarmament and Non-Proliferation, January 2016.

[7]Ziemann and Theiler [5].

[8]Pabian [6].

[9]Goettemoeller [7].

be useful to indicate, for example, a change in normal patterns perhaps indicating the emergence of an undeclared facility or new transportation routes.

A real application of civil society reporting of radiation is Safecast.[10] Safecast was created after the Fukushima incident to report data that otherwise wasn't available, and now has the world's largest open data set of radiation. A mobile, GPS enabled, logging radiation sensor called bGeigie Nano (the "b" standing for bento box) can be built using on-line instructions, and mounted to the outside of a car, bicycle, train, drone or other mobile platform with data captured on a memory card. Most of the collectors for Safecast are Japanese citizens, but data is being collected worldwide. Recently Safecast began collecting air quality data as well. The willingness of volunteers to collect and post data is an indication of what is possible, and the volunteer nature avoids certain legal issues.

As an alternative to a specialized sensor being built and carried by volunteers, a group of researchers at Idaho National Lab developed the concept of using the CMOS sensor in cell phone cameras to record gamma radiation.[11] In this approach, the camera lens is covered so that no visible radiation is detected allowing only high energy gamma or X-rays radiation to hit the sensor. If radiation is detected, an app records and transmits the information. Research to fully understand the accuracy and stability of these types of systems is still occurring[12] and, at the very least, demonstrates the potential of a built-in radiation sensor on a smartphone.

More recently, a research team at North Carolina State University[13] used commercial surface mount resistors and thermoluminescence to measure natural *background* radiation levels indicating the potential application beyond elevated emergency response levels. The dose estimates from the resistors can be measured in a lab in hours compared to weeks needed for biodosimetry. Their intended application was separating the worried well from people exposed to radiation after an event, however being able to measure background radiation levels is powerful.

Finally, social media including Twitter, Facebook, YouTube, Flickr, or other platforms represent ubiquitous sources with vast amounts of information distributed quickly. Social media is extensively utilized in emergency events and already Facebook has created a tool called Crisis Response[14] to respond to a consumer pull. Social media also naturally results in a cueing mechanism for others to collect and post data in regions of interest.

Social media for treaty monitoring is a more nuanced issue, and social media for verification even more so. It is conceivable that social media could be used as another open source data feed for wide are monitoring, especially in combination with other data for corroboration. The idea of using social media in treaties could be included in monitoring and verification provisions.[15]

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[10] blog.safecast.org, accessed October 9, 2019.

[11] Cogliati et al. [8].

[12] Van Hoey et al. [9].

[13] Hayes and O'Mara [10].

[14] https://www.facebook.com/about/crisisresponse/, accessed October 9, 2019.

[15] Lorenz and Feldman [11] and Bufford [12].

*Anti-Neutrino Detection*—In addition to the technologies already discussed, antineutrino detection is an important monitoring approach especially for reactors of key importance. Antineutrino detectors offer a potential solution for continuous, real-time verification of nuclear reactor operation without having to be in the reactor core. The flux of antineutrinos that leaves a reactor carries information about the reactor power and the fissile material inventory, both important for safeguards.

While neutrino detection was discovered in the 1950s, the experiments to understand neutrino oscillation in liquid scintillators that occurred in the 1990s demonstrated much of the physics required for reactor monitoring. Since about 2000, development of detectors that would operate within a few tens of meters from the reactor core has been on-going.

In 2008, IAEA held a workshop on antineutrino detection for safeguards applications that concluded antineutrino detectors have unique abilities to non-intrusively monitor reactor operational status, power, and fissile content in real time, from outside containment.[16] The optimized neutrino detector for reactor monitoring and safeguards would be relatively compact in size and preferably movable. Today, the most likely scenario for antineutrino based cooperative monitoring would be the deployment of a cubic meter scale detector relatively near the reactor. Longer range monitoring is also attractive but requires technical advances. On-going work on neutrino detection includes segmented photomultiplier detectors[17] and high-fidelity computer simulations.[18]

*Data Fusion and Automation*—In order to use data from many different types of sensors, data management and fusion are key. Layers of complexity emerge as sensor data is combined with imagery and social media and as verification is required.

As an example of data fusion and analysis challenges and opportunities, a project is being funded by the United States National Nuclear Security Administration called MINOS—Multi-Informatics for Nuclear Operations Scenarios.[19] In this project, data is being collected on nuclear operations at Oak Ridge National Laboratory where ground truth is available. Different detectors and sensors including radiation, acoustic, seismic, biota, and imagery are being collected and data management and data analytics are then used to draw conclusions about the information to compare with ground truth information. The goal of the work is to see if a highly automated system can answer the question of whether special nuclear material is being diverted from a reactor and is motivated by the large number of declared reactors coming on-line. The project involves ten Department of Energy Laboratories. The data management strategy is to ingest persistent field data; archive, share, and curate the data; and allow analysis to be performed by different groups with flexibility and scalability. The data will include export controlled and Official Use Only information to further

[16]Final Report: Focused Workshop on Antineutrino Detection for Safeguards Application, 28-30 October 2008, IAEA Headquarters, Vienna, Austria, https://www.lefigaro.fr/assets/pdf/AIEA-neutrino.pdf.

[17]Ashenfelter et al. [13].

[18]Stewart et al. [14].

[19]Gaylord [15] and Rajadhyaksha et al. [16].

challenge the data management system. The data ingestion system aims to be entirely automated using domain agnostic user interfaces and multi-petabyte data holdings. The work is just entering the third year of a 7-year planned program.

*Summary*—The challenge of cost-effectively and comprehensively monitoring in the non-proliferation regime is both large and growing with the number of declared sites, increased background levels, and complex geopolitics. However, simultaneously there is an explosion in ubiquitous sensors, drones and mobile platforms, social media, commercially available satellite imagery, sophisticated and sensitive measurement techniques, new data fusion and data sharing approaches, and interested public citizens that could help with the monitoring challenge. A few examples of opportunities and on-going research have been provided that will be critical for future monitoring. If global support is available to mature these approaches and generate the next generation ideas, then monitoring and verification in the increasingly complex environment can remain.

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# Part IV
# Forum-1

# Chapter 14
# Introduction

**Luciano Maiani and Raymond Jeanloz**

In addition to featuring prominent and insightful keynote speakers and convening outstanding panels of experts, the organizing committee of the XXI Edoardo Amaldi Conference wished to ensure that those attending the conference participated in the conference, serving as more than an audience. To accomplish this aim, we built in time for discussion in each session, but we also held a forum at the end of each day. The forum speakers would address broad topics that crossed some of the topics of the day's presentations and discussions, and time would be allowed for other participants to ask questions or remark upon the whole day. This afforded an opportunity to reflect upon ideas, contrasts, and recurring themes.

The Conference was fortunate to have Ambassador Rafael Grossi as the speaker in the first forum. In addition to representing Argentina to the UN organizations in Vienna, Ambassador Grossi was President Designate of the 2020 Nuclear Non-Proliferation Treaty (NPT) Review Conference. According to the UN, with 191 parties to the treaty "more countries have ratified the NPT than any other arms limitation and disarmament agreement." https://www.un.org/disarmament/wmd/nuclear/npt/.

The NPT is in some way related to nearly every issue addressed in the Amaldi Conference, whether peaceful uses, safeguards, or disarmament, the NPT is an important element of the international order.

Ambassador Grossi has taken a distinctive approach in the lead up to the 2020 NPT Review Conference (sometimes called the 2020 NPT RevCon), which he described in his remarks. At the time of the conference, Ambassador Grossi was also a candidate

L. Maiani (✉)
Accademia Nazionale dei Lincei, Rome, Italy
e-mail: luciano.maiani@cern.ch

R. Jeanloz
United States National Academy of Sciences, Washington, DC, USA
e-mail: jeanloz@berkeley.edu



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to be DG of the IAEA (and later was selected). For this reason, he was unable to attend the conference physically, but he participated by video link. He delivered his talk and stayed connected for the discussion afterward. The text of his talk captured here is actually a transcript.

# Chapter 15
# Major Challenges Opportunities and Next Steps for the Parties to the Nuclear Non-proliferation Treaty Approaching the 2020 Review Conference

**Rafael Grossi**

*Editor's Note: The Conference occurred shortly before votes for the next Director General of the International Atomic Energy Agency, and Ambassador Grossi, who was President Designate of the 2020 NPT Review Conference, was also a candidate to be DG of the IAEA (and later was selected). For this reason, he was unable to attend the Conference physically, but he participated by video link. He delivered his talk and stayed connected for the discussion afterward. This is a transcript of his talk.*

I would like to thank the organizers of the Amaldi Conference, one of the most prestigious gatherings we have around this set of international policy issues. So, it is really an honour and privilege to share the podium with those who spoke before. I will lead with my own personal presentation on the NPT Review conference itself, and then have an exchange with you and listen to your ideas and your comments.

By way of introduction, this time the Review Conference comes at a very special moment. It is the 10th Review Conference, which means that it is marking the 50th anniversary after the entry into force of this treaty, the largest idea known in international law which is in itself quite a feat, a remarkable issue. It is also a conference that is coming 25 years after the 1995 Review and Extension Conference, which decided on extending this instrument forever. And it comes at a time where there are lots of events ongoing in the world where multilateral approach to arms control, disarmament, and proliferation have been discussed, and where there are certain trends considered by some as worrisome.

The Review Conference is a great opportunity to reassess how the treaty is being implemented and to have a larger view to other connected questions, matters that

From December 3rd, 2019 - IAEA Director General, Vienna, Austria

R. Grossi (✉)
Ministry of Foreign Affairs, Buenos Aires, Argentina
e-mail: rafaelmgrossi@embargviena.at



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have been added on in a certain sense to the NPT in its pure form without being part of the treaty provisions. There are many other things that are interconnected and are being looked at in this sense. One of the reasons why the conference this time around is being seen as particularly challenging is also because of the fact that 5 years ago we gathered in New York and the Review Conference ended up without a consensus around a final document. Which means that when we gather in New York next year, it will have been 10 years without an agreed view, common view from states parties to the NPT of how the instrument has been implemented and is working. And of course in the course of these past 10 years a number of things have happened affecting or influencing not only the disarmament part of the instrument, but also other sections or other issue areas which are covered as you know in the articles of the treaty that have to do with non-proliferation or the peaceful uses of the atom. So, as we can see, it is a moment where people will be focusing on what happens in New York, people will be judging perhaps the importance, the validity, and the future stability of the multilateral non-proliferation regime on the basis of our deliberations in New York. So, it is a big responsibility upon every single state party to this important instrument.

Of course, one discounts that the political issues, the political problems may have and do have a logic of their own. One cannot predict what will happen when it comes to regional situations in terms of non-proliferation or what will be the state of affairs when it comes to bilateral relations and bilateral understanding between for example the Russian Federation and the United States, which have an impact on disarmament issues. All of these are matters that go beyond the will of one like me, who is going to preside over this effort. What one can do is to professionally try to prepare in an adequate manner, trying to identify these challenges, these opportunities, and design the next steps that could be applied in order perhaps not to guarantee success, because this is something one can never do, but increase substantially the possibility of a successful outcome when we meet next year. This, I think, is a very possible scenario.

One of the novelties this time around is that we need to prepare better and at an earlier stage and perhaps do it in a slightly different way, given the state of affairs in the world, given all these uncertainties that exist, given also the degree of questioning and challenging of multilateral approaches to disarmament and also to non-proliferation. Traditionally, before a few months in advance of the Review Conference, there were a number of consultations in Vienna, in Geneva, and in New York with political groups and parties to understand what major difficulties there will be and what challenges would present themselves. This time you may have noticed that early on, from the beginning of the preparatory cycle, starting with the Dutch presidency back in 2017, continuing with the Polish in the year after that, and finally with the Malaysian chairmanship, we have seen an increased focus and in some cases in the two first chairmanships, efforts of outreach to have an earlier discussion, debate, exchange of ideas on what has been going on.

Once the curtain came down after the third PREPCON last April in New York, I said my work began and it has actually been the case. How did I do it? What did I propose? Well, I felt that it was necessary for the first time to have a dedicated, intensified process of wide consultations led by the president designate. Of course, this does not exclude other efforts that are traditional under other forums, like your conference—track two, track one—but in this case a process led by the President Designate, which would allow me to have a direct conversation with different countries in their specific regions. I did this by way of a process for which resources were needed. One needs to reach out, one needs to bring countries to focal places where you are going to have the discussions and for that I proposed to the European Union a concept and a programme of consultations. The EU gave generously and decided to extend their support. So, I am very grateful to the European partners for the support they gave me to start organizing these meetings. These meetings that I have been conducting so far take the form of regional consultations which have, although not exclusive, have also some focus on the area of peaceful uses of nuclear energy, science, and applications. We have done this because we felt that apart from the very interesting, strategic level of considerations and discussions on issues pertaining to Article 6, disarmament or regional aspects of non-proliferation like the Middle East or things of this sort, there had been in the past some imbalance. Imbalance in the sense that sufficient attention was not being paid to all these areas of peaceful uses, which are actually the areas of greatest and most immediate interest and benefit for the large majority of state parties to the NPT. These are, of course, made possible by scientists because you have this knowledge. So, in our estimation, we thought it was important to do two things: first, to have these regionally oriented conferences, but also to have a dialogue that would bring to the table practitioners, technologist, nuclear regulators, technical support organizations. Those who are really in the daily exercise of work around peaceful uses of nuclear energy and who in my opinion had been largely absent from these conversations in the past. There was nothing wrong with that, but it was limited in a way to the diplomatic corps in the cities in the multilateral disarmament and non-proliferation hubs, like Vienna, New York, or Geneva.

We have started this process, we have already had a regional meeting in Addis Ababa. We went to Africa to start, and there we had a very encouraging beginning with more than 40 countries in attendance. The attendance of the African Commission on Nuclear Energy (AFCONE), the African Union Commission, and we also had the EU represented there. The member states found this kind of approach that we are proposing to be of enormous interest. We are going to have a number of follow up meetings to this coming up: one in Bangkok for Asia, in Mexico for the Latin American and Caribbean region, and the success of this first attempt has been such that more regions and sub-regions have reached out to me requesting more of these consultations, more of these meetings. So much so that I have had to reach out to individual donor countries to fund meetings because the generosity of the EU had already been tapped, and we needed to continue these meetings. One of them will take place in Abuja, Nigeria with a focus on the ECOWAS region, but that is not the only one. There will be one in Pretoria in South Africa. There is going to be one more in Brazil for my part of the world. There is going to be one in Indonesia for Asia. There is a lot of interest in these presidentially led, intensive pre RevCon consultations.

Process is not substance, but process enables substance to be treated in a way that is constructive and conducive to success as opposed to one which is more confrontational.

In these first consultations, a number of interesting friends are starting to manifest themselves. I am describing to you in very general terms what I am seeing as strengths and one thing I see, which is admittedly a general affirmation, but still one that is indispensable and it is necessary before we take the plunge in New York for the Review Conference and this sort of newly found re-commitment to the NPT. I see a lot of convinced countries, north and south, east and west, that see in this norm a norm that is valid, that is present and most of all that is a norm that is a future projection. I say this because I am sure you have been debating this and perhaps we can have an exchange after my presentation. There is a legitimate discussion about the NPT, its validity, the appearance of other norms and considerations of this type and sort. In terms of our preparation for the RevCon, we are working with many countries on an important high-level part of the Review Conference, which is not going to be structured in the sense of having a special document or a special statement, but it is a dedicated effort. We are already working collectively and individually with key countries to encourage their leaders at the Foreign Minister level or ideally at the Head of State level to be present in New York. We would like them to come and to say that we all see in the NPT a normative structure that has meaning and that has value for the future. This finding of mine is something that is giving me a lot of hope and that countries recognize that it will be in no one's interest to see the Review Conference fail.

No one's strategic interests would be served by having a Conference which ends up in disarray or in the absence of agreement. We can discuss about agreement, the form, shape and modality of agreement, but one thing is for sure and this I stress, that as I see it is the will, the collective will of all, to come out of the exercise in the belief and the conviction that the NPT has come out strengthened and not debilitated or weakened after the effort. I have also to indicate that I have seen engagement from the constituencies, as I was saying, from many countries who were not so mobilized, as I said in ministries of energy, science and technology and a community which is bigger and larger than before.

Before I conclude, I would like also to refer to something that is not necessarily part of the formal part of the Review Conference, but rather as part of what I would like to see: That is the presence and relevance of the NPT in a societal manner, outside of the UN building. For the first time, at the Review Conference we are going to have three important events. I do not call them side events because first of all they will not be on the side of the conference, in the sense that we will have to go outside the UN building to have them, but they are very relevant. The first will be a meeting with youth groups from all over the world that are preoccupied and dealing with non-proliferation, disarmament, or international security. It is going to be called "The NPT at 50: The Next Generation." So we are in contact with a good number of networks of young practitioners or young scholars, groups all around the world, on every continent, that have been active and are going to be meeting. We are having this as a very decentralized process. After my original invitation, some of these groups are already meeting and discussing and they will provide us with some elements that I am going to be able to relay to the wider membership for their consideration. So, youth is the first.

The second has to do with gender. I think these days any multilateral approach must be looking at the gender issue as important, not only by way of an increased participation of women, but also by including gender-based perspective to it. I can say this event is going to be called “NPT at 50: Better Together,” and I am working with Women in Nuclear Global and other important groups that exist in many countries to bring also this input from groups that are concerned with the added value that the gender perspective can bring to this issue.

The third and last event I am bringing for the discussion at the NPT Review Conference will be a meeting with global nuclear industries. We will have also a meeting with the major industrial concerns around the world, including not only the traditional nuclear vendors that you may have in mind as I say these words, and I can guarantee you that all of them are participating and are very keen on being there, but also firms around the world that are working with nuclear science and applications. We are going to be establishing or highlighting if you want the link between the NPT and all the industrial or even commercial activities that take place all around the world and are sustained by the treaty. So, I will perhaps stop here since my intention at least with my initial remarks has been to tell you how I, as President Designate of the 2020 NPT Review Conference, have undertaken this effort, from which perspective, how am I looking at it and the things I am doing so far, as I said in the beginning, perhaps not to ensure success because that is impossible for me, but to increase the scope of the dialogue and thereby to also instil the sense of optimism in state parties, to believe that yes agreement is possible, that yes agreement will not necessarily mean that we will solve all the problems that we have in non-proliferation and disarmament, but will continue to strengthen the NPT as one of the tools that we have to deal with those in a successful way. So, I will stop here and will be more than glad to exchange with you further ideas or listen to your questions or comments. Thank you very much for your attention.

# Part V
# Perspectives on Nuclear Non-proliferation—1

# Chapter 16
# Introduction

**Carlo Schaerf**

In April 1961 the Bulletin of the Atomic Scientists published the following cartoon[1]:


At that time in the club there were three Nuclear Weapons States with the indicated number of weapons (USA 22229, URSS 2492, UK 155) and it was estimated that in few decades there would be about twenty since in the Arab World and South America there would be more than one state going nuclear and there would also be proliferation in other parts of Asia.

Today there are nine Nuclear Weapons States: USA (1945) 4000, Russia (1949) 4300, UK (1952) 215, France (1960) 300, China (1964) 270, Israel (1967–73) 80, India (1974) 130, Pakistan (1998) 140, and North Korea (2006) 8. The numbers in parentheses indicate the year of their first nuclear explosion and the other numbers indicate the best estimate of the weapons available to each country in 2017.

[1] Vilny, 4 April 1961, Bulletin of the Atomic Scientists, XVII—4, pg. 148 https://books.google.it/books?id=OQkAAAAAMBAJ&lpg=PA119&pg=PA121&redir_esc=y&hl=it#v=onepage&q&f=false.

C. Schaerf (✉)
Tor Vergata University, Rome, Italy
e-mail: carlo.schaerf@roma2.infn.it



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The USA developed nuclear weapons fearing that Nazi Germany, where fission had been discovered in 1938, could get them first. Fear continuously reinforced by the insistent Nazi propaganda on the imminent deployment of a secret new superweapon that would turn in its favor the outcome of the war. In the end the bombs where used to terminate the war in the Pacific with the expectation, otherwise, of a tremendous human cost for the conquest of the Japanese islands.

The USSR developed them as a response to their successful American military use in a time of increasing rivalry between the two aspiring superpowers.

The UK decided to build its own nuclear arsenal after it was excluded from the American project, to which it had initially collaborated, as a demonstration of autonomous capacity, to have an independent deterrent and to boost its international prestige at the time of the dissolution of its Empire.

France followed to maintain big power status after the humiliations during the war, the loss of its Empire and as a possible national defense against Russia and deterrence against an economically resurgent Germany.

The Chinese nuclear deterrence was motivated by difficulties in Chinese-Russian relations and continuing American non-recognition of the Communist Regime.

The other countries did it because they felt threatened by a hostile country or military alliance which could destroy their country or impose a regime change.

The fact that the first five Nuclear Weapons States were the only one to hold a permanent seat with veto power in the UN Security Council contributed to the opinion that the possession of nuclear weapons provided a special prestige and a status useful in the international power games among nations.

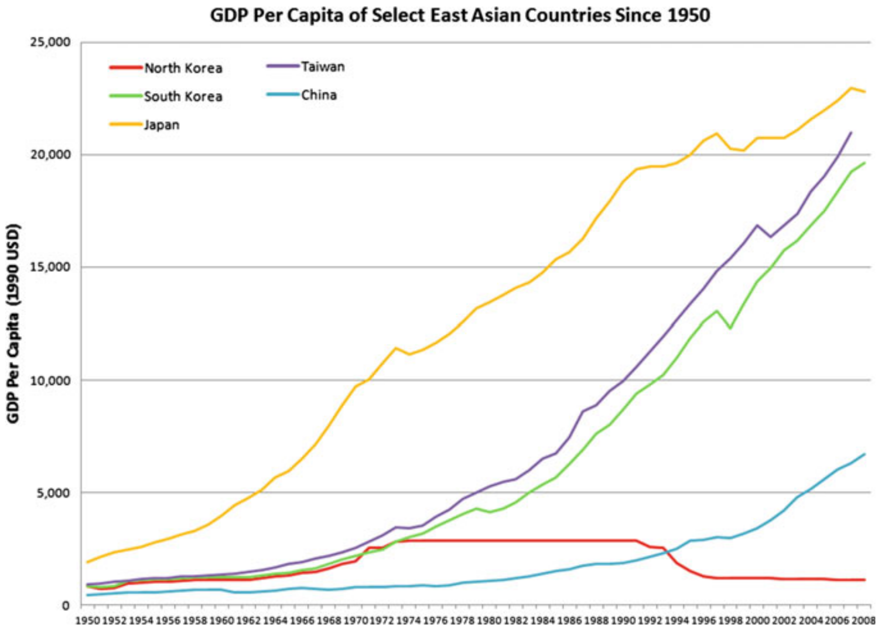
The Treaty on the Non-Proliferation of Nuclear Weapon, NPT, was negotiated between 1965 and 1968 when France and China had already tested nuclear weapons, only experts had heard of Israeli nuclear developments and the Indian nuclear weapons program was in its infancy. It entered into force in March 1970.

Israel probably acquired its first nuclear devices in the years between the two major Arab-Israeli wars: The Six-Day War of 1967, and the Kippur War of 1973. The motivations where its geostrategic inferiority in territory, population, natural resources and military personnel versus the hostile encircling Arab World and the rising prestige, military build-up and threatening politics of President Gamal Abd el-Nasser of Egypt. Israel has consistently refused to admit or deny the existence of its nuclear deterrent but most experts believe that they possess around 100 weapons. Moreover, it is now widely believed that the double flash detected on September 22, 1979 by the Vela satellite in the South Atlantic was a test nuclear explosion conducted jointly by South Africa and Israel.

At the beginning the motivation of the Indian bomb was more the rivalry with China than the problems with Pakistan. In 1962 China had inflicted India a humiliating defeat during their short war on the Himalayan border and in 1964 exploded a nuclear device. The first nuclear weapon was exploded by India in 1974 and was called by Prime Minister Indira Gandhi a "peaceful nuclear explosion." India, like China, has declared to adhere to a "no first use policy."

The development of the Pakistani nuclear bomb is a clear consequence of its continuous conflict with India over Kashmir, the four conventional wars that they fought, its smaller dimensions and economic and conventional military inferiority with respect to India and the difficulty of defending its territory in the event of an Indian conventional ground attach on their common border. Lahore, one of Pakistan most important cities is about 20 km away from the Indian-Pakistani border and there are no natural barriers between them. In these conditions it is widely believed that Pakistan might turn to nuclear weapons in an early stage of a full-scale armed conflict with India.

The Democratic People's Republic of Korea, DPRK, was the result of the division of the Korean Peninsula between the Russian and the USA zones of control at the end of WW II. The successive attempt of the North to annex the South produced the bloody Korean War (1950–53) which ended in an armistice that never became a peace and the two Korean states developed in completely different ways.[2]




After 1974 the South started to develop much faster than the North which stagnated and after the demise of the Soviet Block suffered also a serious famine. Today the GDP Per Capita of the North is less than one tenth of that of South Korea. In these conditions the regime is afraid of being toppled by popular unrest supported by external forces and considers nuclear weapons a deterrent against this possibility.

As its critics correctly point out the NPT is a discriminatory treaty that divides the nations of the world into haves and have-nots. Five nations (USA, Russia, UK, France and China) have the right to possess nuclear weapons while the other nations

[2] https://www.reddit.com/r/dataisbeautiful/comments/20ptd2/gdp_per_capita_of_north_korea_south_korea_japan/.

should not. In exchange they should be supported in the development of peaceful nuclear energy under strict international guarantees. Today four nations have not signed the treaty and not respected its provisions: Israel, India, Pakistan and the DPRK. 190 countries have signed the treaty: all other countries except South Sudan recently independent. This incomplete but substantial success of the treaty is due to the realization by many nations that the military use of even a fraction of the existing nuclear stockpiles will imply the destruction of human civilization, the immediate death of an appreciable part of mankind and an unpredictable fate for the survivors.

In the opening remarks of his acceptance Lecture for the Nobel Prize in Economic Sciences, on December 8, 2005, Thomas C. Schelling said: "The most spectacular event of the past half century is one that did not occur. We have enjoyed sixty years without nuclear weapons exploded in anger. What a stunning achievement—or, if not achievement, what stunning good fortune. In 1960 the British novelist C. P. Snow said on the front page of the New York Times that unless the nuclear powers drastically reduced their nuclear armaments thermonuclear warfare within the decade was a "mathematical certainty." Nobody appeared to think Snow's statement extravagant. We now have that mathematical certainty compounded more than four times, and no nuclear war. Can we make it through another half dozen decades?"

After the traumatic events of Hiroshima and Nagasaki a taboo emerged against the use of nuclear weapons in war. President Truman resisted the pressure of Gen. Douglas MacArthur to use nuclear weapons in Korea and accepted a final ceasefire that confirmed the "status quo ante". The USA suffered also a humiliating defeat in Vietnam but did not resort to the use of nuclear weapons. Similarly, the Soviet Union accepted a defeat in Afghanistan but did not use nuclear weapons. Obviously in both cases it is not clear if the use of nuclear weapons might have changed the outcome of the war.

However, mankind lives with the risk that a minor local conflict might get out of control and escalate to an all-out nuclear war or that a nuclear exchange might be initiated by a mechanical failure or a human error more likely in a time of international tension. As Thomas Schelling points out this is a very real risk and there is now a copious literature on events when the world arrived very close to a nuclear catastrophe which was avoided by sheer luck or the exceptional wisdom of individuals who disregarded prescribed rules of engagements and saved mankind.

The NPT has been accepted by the 190 discriminated countries on the realization that the risk of accidental nuclear war increases with the number of nuclear weapons states and the total number of weapons on earth. Each national nuclear arsenal contributes to increase the probability of a war by accident due to the insecurity of its Command, Control, Communication and Intelligence system (C3I) while the probability that its weapons might explode, be stolen or lost due to mishandling or poor safety increases with the number of weapons under its command. Each nuclear weapon state contributes to the risk of war by accident in proportion to the size of its arsenal and depending on the robustness of its technological and military organization, the reliability of its political system and the tensions in its international relations. All these parameters vary with time and are very difficult to estimate especially in times of political transitions or rapid technological developments.

After the demise of the Soviet Union, the dissolution of the Russian Empire and the following economic crises, there were serious concerns in the West about the safety of its nuclear stockpiles, weapons and fissile materials, and the dispersion of its scientific and technological nuclear-military knowhow.

With the reduced economic interest of nuclear energy and the limited number of new nuclear reactors on order, the main concession of the nuclear weapon states to the have-nots has been the commitment to gradually reduce their nuclear arsenal as envisioned under Art VI of the Treaty. In 1970, at the time the Treaty entered into force the USA had 26,008 nuclear warheads and Russia 11,736. In 2017 they had 4000 and 4300 respectively.[3] The arsenals of the other nuclear weapons states, recognized or non-recognized, for several decades have contained 100–300 weapons each with slow changes in time.

In view of the 2020 quinquennial review conference of the NPT which are the main problems on the table?

Recent years have seen a systematic dismantlement of the Arms Control Regime that provided in the past some form of stability to international relations in the strategic domain. After President G. W. Bush withdrawal from the ABM Treaty in 2002, more recently on May 2018 President Trump announced the US withdrawal from the JCPOA and on February 2019 the US suspension of its obligations under the INF Treaty. While the USA justified these actions as violations on the Iranian and Russian side respectively the truth is probably more complicated.

The JCPOA (Joint Comprehensive Plan Of Action) envisaged a strong limitation of Iranian nuclear developments especially in the field of Uranium enrichment under strict IAEA control in exchange for the lift of the international economic sanctions that were imposed on Iran for its perceived effort to build nuclear weapons in violation of the NPT Treaty. While the IAEA inspectors have found no evidence that Iran has violated its part of the JCPOA agreement, the USA Government and its regional allies have been disturbed by three factors:

- the Iranian developments in the field of ballistic missiles that in the future could carry nuclear weapons on distant targets;
- the emerging documentation that in the past, before JCPOA, Iran was actively pushing the studies for the realization of nuclear weapons despite its ratification of the NPT and IAEA inspections;
- the active and successful participation of Iran, mostly through proxies, to the conflicts ravaging the Middle east in particular in Yemen and Syria against the interests of the USA and its regional allies.

Considering the difficult economic situation for the Iranian people probably the USA has found more promising to reinforce the economic sanctions with the hope of producing serious difficulties to the Iranian regime and be able to negotiate in the future from a stronger position and/or with a friendlier government.

It seems that the attempts of the other signatories of the JCPOA to maintain their obligations to Iran under the agreement and limit the impact of USA sanctions on

[3] http://thebulletin.org/nuclear-notebook-multimedia.

Iran are inconclusive and Iran has resumed a limited and reversible increase in its Uranium enrichment activities.

However, most experts agree that today the highest probability of a nuclear war escalating from a conventional conflict is in the traditional hostility between India and Pakistan over Kashmir.

Since independence India and Pakistan have fought four wars: First Kashmir War in 1947, second Kashmir War in 1965, Bangladesh Liberation War in 1971, limited Kargil War in1999.

Since Pakistan acquired nuclear weapons in 1998 the absence of Indian-Pakistani wars after 1999 is considered by the supporters of nuclear deterrence as one of the effective examples of its application. However, the situation has not been calm with terrorist attacks in Kashmir and sometimes in India by elements probably secretly or indirectly supported by the Pakistani Military Secret Services and Indian sporadic retaliations and repression in Kashmir. Probably the situation did not escalate due to the fact that the side more influenced by Moslem religious nationalism was Pakistan, the weaker of the two nations, while the stronger India was trying to maintain a reasonable peace with its Muslim minority. Today the situation has changed dangerously in India. Its government has obtained a great electoral victory with a platform based on religious Hindu nationalism and looks determined to solve the Kashmir conundrum with a show of force. As we have already mentioned India is conventionally much stronger than Pakistan and an Indian ground attack on their common border could hardly be resisted by the Pakistani Army which might be tempted early on in the conflict to rely on its nuclear weapons. The result for India and Pakistan of an all-out nuclear war between them would be catastrophic but the consequences could be terrible also for the countries in the region and the rest of the world. This under the optimistic hypothesis that other nuclear armed nations will not intervene and the conflict will not escalate to a nuclear world war.

Today the main surviving components of the Arms Control Regime are the NPT, which will undergo its quinquennial review conference in 2020 and the New START that will expire in 2021.

# Chapter 17
# The Iranian National Perspective on Nuclear Non-proliferation

**Kazem Gharib Abadi**

*Threats caused by Nuclear Weapons*—Nuclear weapons are the greatest global threat to international peace and security, since existing arsenals of nuclear weapons alone are more than sufficient to destroy all life on earth. It is concerning that 15,000 such weapons remain with 2200 of them on high alert status or subject to first use nuclear doctrines.[1] In order to ensure security, that is a global concern, global solutions and global participation is required.

*Role of Nuclear Weapons in Security Doctrines*—The global nuclear non-proliferation regime is facing some serious challenges, since some NWS, in particular the US, have not only increased their reliance on nuclear weapons, but also expanded their role in their military concepts and doctrines. The United States nuclear weapons are not only for deterrence, but also pose a serious threat possible to be used not only against Nuclear Weapon States (NWS), but also against Non-Nuclear Weapon States (NNWS).[2] The recently announced US nuclear policy (2018 Nuclear Posture Review) is in violation of Article I and also in full contravention with the core provisions of the NPT.

*Nuclear Disarmament*—The world is at a point where commitment to disarmament must go beyond negotiations in good faith. Among NNWS, considerable distrust flows from the fact that the treaty prevents them from acquiring nuclear weapons, while the NWS have moved so slowly towards disarmament, which can be assessed as a failure of the treaty in providing a plan for disarmament.[3] It is also to be mentioned that NWS have not fulfilled their obligations under Article VI of the

[1] Working Paper submitted by Iran to the second session of the Preparatory Committee for the 2020 Review Conference of the NPT, NPT/CONF.2020/PC.II/WP.27, 11 April 2018.

[2] Ibid.

[3] Statement by Ms. Izumi Nakamitsu (High Representative of the UN for Disarmament Affairs) to the 2019 Moscow Non-Proliferation Conference, 20 October 2017.

K. Gharib Abadi (✉)
Ministry of Foreign Affairs, Teheran, Islamic Republic of Iran
e-mail: k.gharibabadi@mfa.gov.ir



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treaty. Not only negotiations have not been pursued and agreements have not been reached, but also actions towards nuclear disarmament are being taken too slow.

*Inherent link between Nuclear Non-Proliferation and Disarmament*—Disarmament and Non-Proliferation are two sides of the same coin and mutually reinforcing.[4] This along with a commitment to the peaceful use of nuclear energy, form the bargain enshrined in the core of the NPT. As reflected in the Final Document of 2000 NPT Review Conference: "the objective of non-proliferation derives its legitimacy from the larger objective disarmament."[5]

*Israeli Nuclear Arsenal*—Establishment of a Nuclear Weapon Free Zone (NWFZ) in the Middle East is a long lost desire of countries in the region, where the unbridled reckless nuclear weapon program of Israel threatens the region and beyond. Despite the fact that Israel is not a party to any of the disarmament and arms control treaties, it never declared its intention to accede to the NPT and continues its nuclear weapons program without placing them under the IAEA Safeguards. There is no clear perspective on the establishment of a NWFZ in the Middle East due to opposition of the US and some other States.

*Iran and Non-Proliferation*—The Islamic Republic of Iran was the first country that proposed the Middle East Nuclear Weapon Free Zone in 1974. As a member to all Weapons of Mass Destruction Treaties (WMD), Iran implements the Comprehensive Safeguards Agreement (CSA) and also Additional Protocol on a voluntary and provisional basis under the Joint Comprehensive Plan of Action (JCPOA). The JCPOA is also an important document in nuclear activities, to which Iran concluded alongside with other parties. Based on the Fatwa by the Supreme Leader the production, deployment and use of nuclear weapons, similar to the other WMD are prohibited. On the other hand, nuclear weapons have no stance in Iran's security doctrine, as it was proved during the time where Iran was victim of chemical weapons, without producing and using them.

*JCPOA (Nuclear Deal)*—The Joint Comprehensive Plan of Action is a detailed, 159-page agreement with five annexes reached by Iran and the P5 + 1 (China France, Germany, Russia, the United Kingdom, and the United States) on July 14, 2015.[6] The nuclear deal was endorsed by UN Security Council Resolution 2231, adopted on July 20, 2015.[7] January 16, 2016, is the JCPOA Implementation Day, since the IAEA certified that Iran has taken the key steps to restrict its nuclear program.[8]

The JCPOA seeks comprehensive lifting of all UN Security Council sanctions as well as multilateral and national sanctions related to Iran's nuclear program, including steps on access in areas of trade, technology, finance and energy. Thus, its full

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[4] Beenish Pervaiz, Challenges and Solutions for Non Proliferation, 22 November 2012.

[5] Final Document of 2000 Review Conference of the Parties to the NPT, NPT/CONF.2000/28, New York, 2000.

[6] Joint Comprehensive Plan of Action, Vienna, 14 July 2015, Annex A to the UNSC Resolution 2231.

[7] Resolution 2231 of the Security Council, S/RES/2231, 20 July 2015.

[8] Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the I.R. of Iran, GOV/2015/65, 18 November 2015.

implementation will ensure the exclusively peaceful nature of Iran's nuclear program. As a multi-party agreement, based on reciprocity, its scope, provisions and timeframes are based on a delicate, negotiated and multilaterally-accepted balance that cannot be widened, altered or renegotiated.

*Iran's Commitments*—By implementing the JCPOA, Iran committed to keep its enrichment capacity at Natanz at up to a total installed uranium enrichment capacity of 5060 IR-1 centrifuges for 10 years and also to keep its level of uranium enrichment at up to 3.67%. It also committed to convert the Fordo facility into a nuclear, physics and technology center, refrain from any uranium enrichment and uranium enrichment R&D and from keeping any nuclear material.

Iran keeps its uranium stockpile under 300 kg for 15 years, redesigning and rebuilding a modernized heavy water research reactor in Arak, keeping its accumulation of heavy water at the level of 130 tons, shipping out all spent fuel for all future and present power and research nuclear reactors, not engaging in any spent fuel reprocessing or construction of a facility capable of spent fuel reprocessing or reprocessing R&D activities leading to a spent fuel reprocessing capability for 15 years, provisional application of the Additional Protocol, and full implementation of the "Roadmap for Clarification of Past and Present Outstanding Issues," are also among other commitments that have been accepted by Iran under the Deal.

*Commitments by of other Participants*—Annex II to the JCPOA is based on two main parts, which are lifting of sanctions and sanction lifting effects. According to the Deal, all sanctions, including in the following areas should be terminated: financial, banking and insurance measures; oil, gas and petrochemical sectors; shipping, shipbuilding and transport sectors; gold, other precious metals, banknotes and coinage; nuclear proliferation-related measures; metals, software, arms; and listing of persons, entities and bodies. It is to be said that sanctions should not be terminated only on paper, rather as a result of sanction lifting specified above, all those activities, shall be practically allowed, beginning on implementation day.

*Unilateral Withdrawal of the USA*—Unlike Iran, which has fulfilled its undertakings under the JCPOA, as repeatedly and consistently verified by the IAEA, the United States has consistently failed—since "implementation day", and particularly after the assumption of office by President Trump—to abide by its commitments under the JCPOA.

On 8 May 2018, the President of the United States announced his unilateral and unlawful decision to withdraw from the Joint Comprehensive Plan of Action, in material breach of Security Council Resolution 2231 (2015) to which the JCPOA is annexed.[9] From the day of withdrawal, the United States continues to exert maximum pressure to dismantle the JCPOA and the UNSC resolution 2231 and had been persistently violating the terms of the agreement almost from its inception, even preventing other JCPOA Participants from fully performing their obligations. Sanctions by the USA have nullified the lifting of sanctions by the European Union.

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[9]Remarks by President Trump on the JCPOA, 8 May 2018, available at: https://www.whitehouse.gov/briefings-statements/remarks-president-trump-joint-comprehensive-plan-action/.

Needless to say that the United States of America is in the forefront of imposing exterritorial unilateral sanctions and has spared no efforts to resort to trade sanctions, interrupt financial and investment flows, freeze assets, travel bans, to name just a few, in order to impose its will over other States. Acting as a self declares global police, it is trampling on every international law and norm.

*Joint Commission and the Sanctions*—During this time, the Islamic Republic of Iran invoked the mechanism envisioned in Paragraph 36 of the JCPOA, and the Joint Commission met twice at the level of political directors and twice at the ministerial level. In these meetings, the remaining participants explicitly acknowledged that the lifting of sanctions—and the economic dividends arising from it for Iran—constitutes an essential part of the deal. The foreign ministers of remaining JCPOA participants committed to design "practical solutions" aimed at normalizing and even enhancing economic cooperation with Iran.[10]

The Islamic Republic of Iran, in response to the request of the Heads of Governments of the remaining JCPOA participants, pledging prompt remedial actions, agreed to postpone adoption of the measures envisaged under paragraphs 26 and 36 of the JCPOA, and exercising utmost prudence, while continued to fully implement all its commitments under the JCPOA. Nevertheless, apart from issuing numerous political statements and support, no operational mechanism has been put in place to counter US sanctions and to compensate for them in terms of sanction lifting effects, as specified in Annex II of the JCPOA that allows for the normalization of trade and economic relations with Iran.

*Iran's Decision: Legal Basis*—In the absence of effective and meaningful measures by the other JCPOA participants to remedy the most devastating effects of the US actions, Iran has decided to undertake practical measures to exercise its recognized rights under Paragraphs 26 and 36 of the deal, to secure its rights and restore balance to the obligations set forth. As Para 26 of JCPOA states: "…Iran has stated that it will treat such a re-introduction or re-imposition of the sanctions specified in Annex II, or such an imposition of new nuclear-related sanctions, as grounds to cease performing its commitments under this JCPOA in whole or in part".

Also according to Para 36 of the JCPOA: "If Iran believed that any or all of the E3/EU + 3 were not meeting their commitments under this JCPOA, Iran could refer the issue to the Joint Commission for resolution … if the complaining participant deems the issue to constitute significant non-performance, then that participant could treat the unresolved issue as grounds to cease performing its commitments under this JCPOA in whole or in part …".

In response to US withdrawal from the JCPOA and the re-imposition of its unilateral sanctions, Iran has decided "to cease performing its commitments in part" as of 8 may 2019 on a 60 day basis.[11] Indeed, the aforementioned violations by the US administration, and provocative actions, inter alia, the US decision to halt Iran's oil trade and sanctions on international nuclear cooperation with Iran, provided for

[10]Chair of the JCPOA Joint Commission Statements, 28 July 2019, 28 June 2019, 24 September 2018, 6 July 2018.

[11]Decisions by Iran's Supreme National Security Council, 8 May 2019.

Iran "grounds to cease performing its commitments under the JCPOA in whole or in part". Therefore, the decision by Iran is fully consistent by the terms of the Deal, including those related to dispute resolving mechanism enshrined in paragraph 36 of it.

*JCPOA and Providing Access to the IAEA*—All the above mentioned took place, while Iran exercised maximum restraint and patience and fully implemented its commitments under the deal, which has been verified by 15 reports of the IAEA's Director General. The IAEA has the most robust verification mechanism in Iran. It is worth noting that while Iran has only 3% of total global nuclear installations, receives 20% of all IAEA accesses. In 2018 only, 258 out of 421 (85% of inspections in 50 states that are implementing CSA and AP without broader conclusion in place) took place in Iran and 88% of present day inspections amounting to 1000 person-days in the same group, were conducted in Iran.[12]

*Conclusion*—Starting negotiations for disarmament with strong monitoring and implementation verification mechanisms in a reasonable time frame, is a dire need. A real progress towards disarmament is essential to the sustainability of the Non-Proliferation regime in the long run.[13] The treaty survival depends on whether a comprehensive and non-discriminatory framework for disarmament will be established or not.[14] As former Secretary General of the UN said: "The only world that is safe from the use of nuclear weapons in a world that is completely free of the nuclear weapons themselves."[15]

The establishment of the Middle East Nuclear Weapon Free Zone is of great importance. The exertion of sustained pressure on Israel to accede to the NPT, promptly and unconditionally, as a Non-Nuclear Weapon Party, and to place all of its nuclear installations and activities under the IAEA Safeguards should be one of the main actions.

It is to be said that the JCPOA served as a good base for confidence building between Iran and other parties to the deal. What has been proven so far is that the deal not only has turned Iran's nuclear program from an unnecessary crisis to a framework for cooperation in the field of peaceful use of nuclear energy and non-proliferation, but also has established Iran's position to a region free from nuclear weapons and now it's the high time to extend it to the whole region.[16]

It has become crystal clear by now that Iran has shown its utmost restraint in response to the decision of unilateral and illegal withdrawal by the US from the JCPOA and continued to meet its obligations under the Deal. In turn, Iran should continue to receive the economic benefits it is entitled to. So, this imbalanced approach to the rights and obligations cannot be sustainable. Iran still believes on the importance

[12]The IAEA Safeguards Implementation Report for 2018, GOV/2019/22, 6 May 2019.

[13]Mohamed ElBaradaei, "Some Major Challenges: Nuclear Non-Proliferation, Arms Control and Terrorism," Statement to the Symposium on International Safeguards, 29 October 2001.

[14]Beenish Pervaiz, ibid.

[15]Ms. Izumi Nakamitsu, ibid.

[16]Dr. Javad Zarif, Iran's Foreign Minister, Iran Has Signed a Historic Nuclear Deal and Now it's Israel's Turn, Guardian, 31 July 2015.

of diplomacy and multilateralism as a practical means to resolve disputes and will continue to support the JCPOA and is ready to consult with international community, in particular with remaining participants to find effective practical ways to preserve the deal.

Now, it is the remaining countries' turn to prove their good-will and take serious and practical steps to preserve the JCPOA. Instead of demanding that Iran unilaterally abide by a multilateral accord, remaining parties should uphold obligation.

# Chapter 18
# The Pakistani National Perspective on Nuclear Non-proliferation

**Muhammad Naeem**

I would like to thank the organizers of the 21st Amaldi Conference for giving me an opportunity to speak on Pakistan's perspectives on nuclear non-proliferation. In doing so I shall cover aspects of nuclear safety, safeguards, nuclear security and other measures to strengthen non-proliferation efforts in Pakistan.

Ladies and Gentlemen,

Pakistan is a country of over 220 million people which makes us the 6th most populous country of the world. Pakistan is a developing economy, which is seriously threatened by climate change and we are making best efforts to meet the UN sustainable development goals.

In the contemporary world, concerns about nuclear proliferation and security have taken a centre stage as these are thought to be dangerous threats to international peace and stability. Pakistan remains committed to the objectives of enhancing non-proliferation efforts. For the purpose Pakistan has been fully engaged with international community for promotion of nuclear safety, security and safeguards.

The areas where Pakistan has instituted measures in the broader realm of nuclear non-proliferation and nuclear security are, legislative, legal, regulatory, institutional development, enforcement and international cooperation. I shall dilate upon each of these, but let me first underscore that Pakistan appreciates the measures taken by IAEA and UN through various conventions and initiatives.

This conference would enable us to coordinate and synergize the work of the international community in the theme areas of this conference.

Ladies and Gentlemen,

The genesis of Pakistan's nuclear program was when we joined the US 'Atoms for Peace' programme in late fifties. We were among the founding members of the International Atomic Energy Agency (IAEA).

M. Naeem (✉)
Pakistan Atomic Energy Commission, Islamabad, Pakistan
e-mail: chairman@paec.gov.pk



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Since the establishment of Pakistan Atomic Energy Commission in 1956, we have been working to use nuclear science & technology for socio-economic development and have made some significant strides.

To follow the military path of nuclear energy was forced on Pakistan by events of separation in 1971 and so-called peaceful nuclear explosion in our neighborhood in 1974. Despite this, our military nuclear capability is for self-defence and we have always demonstrated restraint and responsibility. From 1974 to 1998, Pakistan made several proposals for keeping South Asia free of nuclear weapons; which also included proposals for application of Comprehensive Safeguards Agreements in South Asia. However, the events in 1998 ended the prospects of a nuclear weapons free South Asia.

I would like to raise here briefly the spectre of serious developments taking place in our region, marked by one county's quest to establish its hegemony despite pending UN resolutions. Its relentless accumulation of arms and nuclear capabilities coupled with aggressive policies & doctrines is likely to affect the regional stability. Suffice to say that Pakistan is compelled to take certain measures in safeguarding our security and sovereignty.

For us, the best guarantee, for peace and stability and against any arbitrary actions by bigger powers, remains a strong non-discriminatory rule-based global order. A robust non-proliferation regime is the central pillar of such a rule-based order, and the IAEA safeguards are a critical component of this regime.

Since our nuclear testing in 1998, Pakistan started formalizing its nuclear institutions under unified authority called 'National Command Authority' (NCA) established in 2000, with Strategic Plans Divisions (SPD) as its secretariat. NCA is the apex decision making body, chaired by the Prime Minister which exercises complete control over all aspects of policy, procurements, operations, employment and nuclear security; in open and military aspects. Within this framework, SPD develops technical solutions, personnel and human reliability programs, and intelligence capabilities to deal with nuclear security, non-proliferation and WMD terrorism.

When it comes to non-civilian area, I can assure this August House with confidence that all our strategic assets are fully secure and under the effective centralized command and control of the National Command Authority.

Ladies and Gentlemen,

Pakistan is among the oldest operators of nuclear power plants. Currently, PAEC operates five nuclear power plants while two 1100 MWe each near Karachi are expected to be connected to grid in next two years. In line with our Government's vision, our national goal is to expand our nuclear energy capacity to about 40,000 MWe as envisaged in our National Nuclear Energy Vision 2050.

In pursuance of our commitment to the global non-proliferation objectives, Pakistan continues to support the IAEA safeguards system and has always worked with other IAEA member States in strengthening the safeguards system while ensuring its credibility, objectivity and robustness. Pakistan accords highest priority to the nuclear safety at the plant and the regulatory levels. A system peer reviews is supplemented by WANO and IAEA's missions. After Fukushima accident, Pakistan carried out detailed assessment of its NPPs. We revised all safety parameters, emergency preparedness and response besides improving the operator's training, response protocols and procedures.

All our civilian nuclear power plants remain under IAEA safeguards with an excellent implementation record and we intended to continue this approach in the future as well. In order for safeguards to remain as guarantor in the non-proliferation regime, it is essential that there be no loopholes, which could allow any state to pursue pathways of diversion. States with similar safeguards measures without any exception. Non-discriminatory and even-handed approaches are essential for the credibility of the IAEA safeguards system.

Ladies and Gentlemen,

Nuclear safety and security continues to remain subjects of paramount importance for Pakistan. We take them seriously because of our own national interest. I earlier spoke a little about our extensive civilian nuclear program. It is of utmost importance that the civilian nuclear program continues to enjoy the public confidence in Pakistan and that can happen only when nuclear technologies are pursued in safe and secure manner.

Safe and sustainable nuclear energy is essential to advance our development agenda. We believe that it is imperative for the sustainability and expansions of nuclear power. Pakistan has been running a safe civilian nuclear power program for about five decades.

Overtime, the Pakistan Nuclear Regulatory Authority (PNRA), an autonomous body, has developed a sustainable nuclear safety regulatory system for the power reactors, and established response and recovery capabilities for radiological sources. Our efforts in nuclear safety were publicly recognized by the late Director General Yukiya Amano when he visited Pakistan in early 2018.

PNRA continues to review and update its regulations in light of extensive national experience and IAEA safety standards. For instance, during preceding year three additional regulations have been issued. The regulatory oversight program of PNRA is based on International proven practices and has been subjected to peer reviews by the experts from other nuclear regulatory bodies through various IAEA Expert Missions such as International Regulatory Review Team (IRRT), Education and Training Appraisal (EDuTA) and International Regulatory Review Service (IRRS).

In pursuit of safe use of nuclear technology, PNRA is now building capacity of other embarking countries. Pakistan has provided expert services to different countries in Asia, Africa and Europe for developing nuclear safety and physical protection infrastructure for nuclear power programs. For instance, it has recently concluded an agreement with Nigerian Regulatory Authority under IAEA aegis and arranged a training course for Malaysian Atomic Energy Licensing Board.

As a party to the Convention on Nuclear Safety, the Convention on Early Notification of Nuclear Accident, and the Convention on Assistance in case of a Nuclear Accident or Radiological Emergency, Pakistan has been contributing to the nuclear safety framework. We are also implementing instruments such as Code of Conduct on Safety and Security of Radioactive Sources, along with its two Supplementary Guidance documents, and the Code of conduct on the Safety of Research reactors.

Pakistan Atomic Energy Commission is running 18 nuclear oncology medical centres where approximately one million patients are treated each year. We have been actively using radioactive sources in cancer therapy in these medical centres in the country to treat local and patients from our neighboring countries. Besides this, PAEC also runs four agriculture and bio-technology research centres, which have produced over a hundred high yielding, drought and pest resistant crop varieties and are also working in other nuclear techniques for pest management. Our regulatory authority maintains and inventory of all radioactive sources in the country and also conducts periodic physical inspections to ensure their safe management throughout their lifecycle.

Having made considerable progress in the nuclear research and development, Pakistan has also attained significant supplier's capability. We have in the past and are currently also manufacturing heavy parts and equipment and providing technical assistance to CERN.

Ladies and Gentlemen,

Now I will highlight some of the efforts we have made in nuclear security. Pakistan strongly supports the fundamental principle that nuclear security is a State Responsibility. Effective measures taken at the national level contribute to nuclear security internationally.

Pakistan has always maintained that the IAEA has a central role in coordinating international activities in the field of nuclear security, which leads to strengthening nuclear security globally. We acknowledge the IAEA's role in assisting states, upon their request, in their efforts to put in place effective nuclear security measures.

As a responsible state with advance nuclear technology, Pakistan has developed and deployed a comprehensive nuclear security regime that encompasses not just physical protection of materials and facilities, but also material control and accounting, transportation security, prevention of illicit trafficking, border controls, and have prepared plans to deal with any future radiological emergencies.

Our large security force is professional and agile and it also includes a Special Response Force (SRF) which has a rapid air lift capability based on dedicated aviation resources. An integrated intelligence system has been instituted to provide depth in defense. Multi layered defence is the corner stone of Pakistan's nuclear security architecture and deploys a variety of physical and technological systems. We run a strict Personnel Reliability Programme to deal with non-proliferation and insider threats, maintaining a Material Protection Control & Accounting (MPC&A) Program with a holistic goal of physical security, safety, accountability and verification.

We regularly review and update our nuclear security regime in the light of IAEA guidance documents and the international best practices. We have developed "Regulations on Physical Protection of Nuclear Material and Nuclear Installation (PAK/925)", which are based on IAEA nuclear security recommendations contained in INFCIRC/225/Rev5.

Pakistan is party to important international instruments and conventions related to nuclear security; for instance, the Convention on Physical Protection of Nuclear Material and its 2005 Amendment. We have been participating in the IAEA Incident and Trafficking Database (ITDB).

Pakistan's Centre of Excellence for Nuclear Security has grown into a regional and international hub for nuclear security training and has conducted various IAEA courses with participants from over 45 countries. It won accolades from the late DG IAEA when during his visit to the Centre in March 2014, said "It is very impressive that you organize the training in a very systemic and operational manner". The previous US Under Secretary Rose Goettemueller had also appreciated the Centre of Excellence on record during a US Congressional hearing.

As a further demonstration of our commitment towards nuclear security, Pakistan has recently joined Nuclear Security Contact Group by subscribing to INFCIRC/899. Moreover, Pakistan is also actively considering undertaking an IPPAS Mission at the earliest opportune time.

A systematic effort to upgrade nuclear security at all Nuclear Power Plants (NPPs) and nuclear medical centres is being continuously undertaken. Under the IAEA-Pakistan Nuclear Security Cooperation Program, physical security at Karachi Nuclear Power Plant (KANUPP) is being upgraded through installation of a sophisticated land-based physical protection system. Moreover, in order to address threat from sea-side, an integrated Maritime surveillance System (IMSS) is being installed to enhance detection and response capabilities. Similarly, physical protection measures at the 14 nuclear centres with category-1 sources are being upgraded.

As part of its safety and security regime, Pakistan has established PAEC Emergency Response and Coordination Centre (PERCC), which remains operation around the clock to coordinate response activities in case of any emergency at PAEC facilities. A Nuclear Emergency Management System (NEMS) has been established at the national level to handle nuclear or radiological emergencies. Under NEMS, 30 Radiological Assistance Groups (RAGs) have been established and trained to perform response actions in the affected areas. Several training courses for the first responders, emergency response personnel and officers have been conducted for emergency preparedness and response.

National Radiation Emergency Coordination Centre (NRECC) and nuclear security Emergency Coordination Center (NuSECC) have been established at the headquarters of our regulatory authority as a national contact point with the international community and the IAEA.

Over the years, Pakistan has acquired considerable experience as well as expertise in the field of nuclear safety and nuclear security. We are willing to offer assistance to interested States in response to specific requests in this area.

In furthering our non-proliferation efforts, Pakistan has also instituted stringent national export control regime, which is at par with best international standards. The regime consists of legislative, regulatory, administrative and enforcement measures. Comprehensive Export Control legislation was enacted in 2004, also published as IAEA document (INFRCIRC/636 Nov 30, 2004).

Strategic Export Control Division was established in 2007 at our Ministry of Foreign Affairs as an implementing arm which contributes towards non-proliferation and security through effective export management of sensitive goods and technologies. Pakistan's National Control List (NCL) are harmonized with the export controls maintained by NSG, Australia Group and MTCR, which are regularly updated, last one published as INFCIRC/928 in January 2019.

The national Detection Architecture (which is a work in progress) includes use of detection devices at several entry and exit points as well as other random check points to deter, detect and prevent illicit trafficking of nuclear and radioactive materials. The integrated Cargo Container Control (IC-3) facility at Port Qasim near Karachi is a Container Security Initiative (CSI) compliant port. Pakistan is among the few states who have submitted five reports to the UN Security Council's 1540 Committee.

Ladies and Gentlemen,

Pakistan recognizes its obligations as a responsible nuclear State. We have strengthened our national control systems, nuclear export controls and nuclear security system at par with international standards. Pakistan has clean sheet with regards to nuclear safety and security incidents. In last two decades there has not been even the slightest of blemish on Pakistan's part with regards to nuclear proliferation.

Having said this, it is imperative for global non-proliferation norms to flourish in such a way that no amount of political, strategic or commercial interests should be allowed to side-step it. Civil nuclear cooperation should follow only after such sufficient legally binding assurances on non-proliferation are obtained. However, unfortunately we have seen instances where cooperation increasingly taking place despite the fact that pathways exist for diversion. This is resulting in huge imports of fissile materials and technologies thereby significantly adding to their military capability. On the other hand, barriers are placed in the way of gaining equitable and non-discriminatory access to the international civil nuclear market for legitimate peaceful uses.

Pakistan believes in an equitable, non-discriminatory and criteria-based approach to advance the universally shared goals of non-proliferation and promotion of peaceful uses of nuclear energy. Pakistan applied for membership of the Nuclear Suppliers Group (NSG) in May 2016. As a country with significant nuclear program and advance nuclear technology with ability to supply items controlled by the NSG, Pakistan's participation will further the non-proliferation objectives of the Group. Pakistan, therefore, sees its NSG membership as a mutually beneficial proposition.

We also strongly believe that there is a need to strengthen global non-proliferation norms. But any progress will only be sustainable, if it is based on non-discriminatory criteria and does not seek to maximize the interests of few at the expense of global and regional strategic stability.

Let me thank the organizers of Amaldi Conference once again for inviting me and providing me the opportunity to present Pakistan's perspective on these important issues.

Thank you indeed.

# Chapter 19
# Adapting Non-proliferation Approaches to a Changing World: A European Expert's Viewpoint

**Caroline Jorant**

*Introduction*—The first reflections over the development of nuclear energy and the need for a non-proliferation regime were engaged in the aftermath of WW2 and publicized in 1953 by President Eisenhower in his historical speech, "Atom for Peace".

The peaceful uses of nuclear energy developed very significantly since then, demonstrating the success of the non-proliferation policies and mechanisms, contradicting President Kennedy 's fears expressed in 1963 that as many as 15–25 Nations would be possessing nuclear weapons in the 1970s. We are some 50 years and this number is "limited" to 9 States.

In terms of non-proliferation, the regime instituted in the late 50s/60s has also evolved in response to specific challenges or crises, in particular with the peaceful atomic explosions in India or the findings in Irak where the IAEA was not empowered to detect non declared activities. Other situations (Iran- DPRK) have not been met with an evolution of the institutional framework but rather have demonstrated some flaws or weaknesses of the system.

In 2004, Libyan clandestine activities were put to an end thanks to the negotiations launched by the US and the UK. Finally, another major violation of non-proliferation commitments was discovered with the clandestine construction of a reactor in Syria. This situation was met by the unilateral Israeli military action that destroyed the plant.

In terms of nuclear energy, the period is characterized by an expansion both in its contribution to the energy balance and geographically. Today as many as 30 countries have at least one NPP (1) with major developments in Northern America but also in Europe, Russia and Asia, mainly Japan and China.

C. Jorant (✉)
Strategie de Developpement et Reglementations Internationales Consulting, Paris, France
e-mail: cjorant.zaleski@orange.fr



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However, the Chernobyl accident in 1986 seriously impacted the development of nuclear energy namely in the EU and the prospects for an anticipated "nuclear renaissance" was just killed.

The perspectives for nuclear energy development in the next 30 years are uncertain but the global nuclear landscape will be very different.

The nuclear non-proliferation regime covers both horizontal and vertical proliferation and thus includes efforts towards the elimination of nuclear weapons. However, although there are connections between both aspects, this paper focuses on the horizontal proliferation, that is on efforts to deter, or possibly detect and react to proliferation attempts from States not possessing nuclear weapons.

*The non-proliferation regime today is a complex but rather comprehensive global framework with some weaknesses*—The nuclear non-proliferation regime is heavily dependent on the Nuclear Non Proliferation Treaty (NPT) that was open to signature in 1968. It is the most universal International Treaty while being subject to recurring criticisms as being unfair given the different status and obligations of NNWS and NWS. It is flawed with the legal and practically the political impossibility to offer any derogatory status to allow the adherence of news States or "de facto" States, possessing nuclear weapons. It also lacks any efficient provisions to deal with the case of non-compliance or breakout. It's limits where demonstrated when DPRK chose to step out of its commitments under the Treaty using a "national security" clause without allowing a proper international response.

However, the NPT has gained almost universal adherence, has been indefinitely prorogated in 1995, and is complemented with a series of agreements that can be seen as implementing tools.

The NPT calls for States to put nuclear material under the safeguards of the IAEA.

Although the obligations are different between a comprehensive safeguards agreement, a Verification Offer Agreement and a facility type agreement, all States with significant nuclear activities do have a safeguards agreement in place. This includes the 5 Nuclear Weapon States but also India and Pakistan although not Parties to the NPT.

Nuclear non-proliferation assurances are delivered by the IAEA thanks to the safeguards strategy and verification work implemented by its Department of Safeguards.

"The objective of IAEA safeguards is to deter the spread of nuclear weapons by the early detection of the misuse of nuclear material and technology. The IAEA verifies that nuclear facilities are not mis-used and nuclear material is not diverted from peaceful uses".

The safeguards' approaches and the concepts applied have been refined over the years.

Today the State level Approach based on the analysis of an acquisition Path assessment is implemented in 54 States whereby all plausible way for a State to obtain nuclear material usable in a nuclear weapon or in a nuclear device are analyzed and technical objectives are to be met to detect any diversion.

Most but not all safeguards agreements are now complemented with an Additional Protocol that allows the IAEA to get extended access and information to be able to detect not only the diversion of declared material but also possible clandestine activities.

The task of the safeguards Department has been growing with those new agreements but also with specific efforts that have to be devoted when a situation arises (in particular nowadays with the Iran case) where new inventories are to be taken and new safeguards schemes are to be designed and implemented. This calls for additional financial and human resources. Out of the 2019 IAEA budget of 375.2 Million 145 M€ are allocated to the Department of Safeguards, which represents about 39% of the total budget, with a staff of 918 persons in 2018.

Other safeguards activities are carried out at a regional level, in the EU under the Euratom Treaty and between Brazil and Argentina through a common body, ABBAC.

These safeguards and controls in turn can partly support IAEA's activities in the countries covered by such arrangements.

The safeguards system is itself complemented with the Nuclear Suppliers' Group export control guidelines. These Guidelines only reflect political commitments of its Members and are not legally binding. However, it is a very useful tool to disseminate good practices, review and agree on the nuclear and dual use items and technology which export should be subject to specific conditions, restraint or even refusal (denials). Most of supplier States and States of transit are Members of the NSG. NSG suppliers require to have a bilateral agreement in force to allow the export of sensitive nuclear goods and services. Thanks to the NSG, the main conditions that are requested to importing States and contained in bilateral nuclear arrangements are more and more standardized (full scope safeguards agreement, export control, or no export without agreement, adoption of international safety and security Conventions and implementation of IAEA's recommendations).

Such cooperation agreements can also be required at a regional level as it is the case with Euratom.

*The intersection between security and non-proliferation*—Nuclear non-proliferation policies as described above generally address attempts by a State to acquire a nuclear weapon or device. However, individuals or groups of individuals may try to acquire, nuclear material, technology or even weapons for terrorist purposes or in exchange of money or other goods or favors from proliferating States.

In that respect, nuclear security measures may be considered as part of nuclear non-proliferation policies.

Measures to deter, detect, and possibly recover material obtained through theft do complement the institutional, legal, or political measures described above.

Responsibility over security issues are left to each State, with the IAEA developing guidelines, technical support and a forum for exchanging on good practices. At the international level however, the CPPNM was adopted in 1980 and entered into force in 1987 in particular to ensure international transport of nuclear material would be covered by agreed security measures/levels. An amendment to the Convention entered into force about 30 years later, in 2006. This amendment extends the scope of the CPPNM to material, facilities and storage at domestic locations and in case of sabotage. It also extends the scope for international cooperation to recover material or mitigate the radiological effects of acts of sabotage or terrorism.

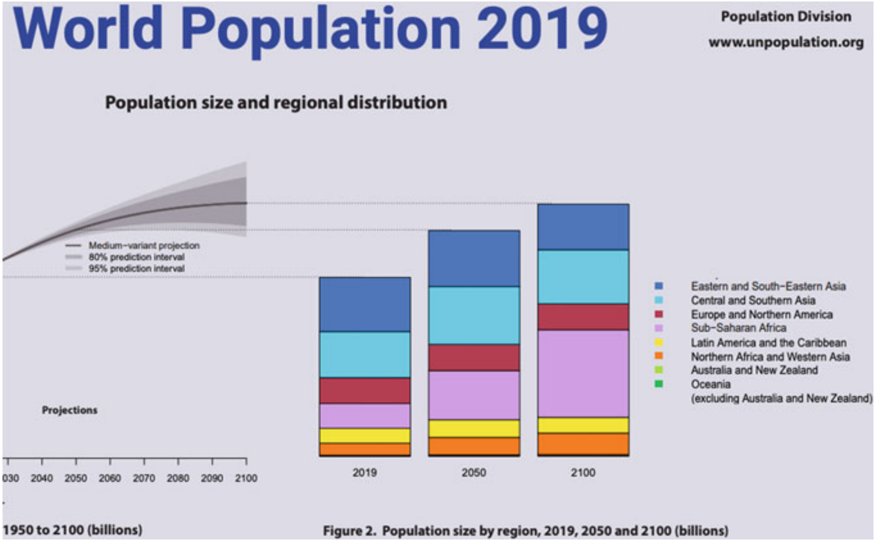


**Fig. 19.1** Population size by region, 2019, 2050 and 2100 (billions)

Both Convention and Amendment are legally binding instruments.

Another Convention to be mentioned here is the International Convention for the Suppression of acts of nuclear terrorism that was adopted in 2007. This convention aims at promoting international cooperation to prevent acts of terrorism and punish the perpetrators.

*A changing nuclear landscape*—When Looking ahead with a 20/30 years horizon and trying to assess what may be the major challenges to the regime apart of political risks of breakouts, it is necessary to have a fair vision of the nuclear landscape; where nuclear will be developing and what types of technologies will be available.

*Changing Nuclear distribution*—The world population is predicted to go up to 2 billion in 2050, with 9.7 billion persons, with the largest increase in sub-Saharan Africa (double by 2050).[1]

The distribution of the world population will be changed as illustrated on the following graph (Fig. 19.1).

This increase in population will go together with the growth of energy demand and a larger share of electricity demand. In that context, IAEA[2] predicts in both its high and low scenarios, a net increase in nuclear energy output, (more than double the 2018 output in the high scenario and about +16% in the low scenario), although this will not

[1]"Report of the UN issued on 17/06/2019 "Nine countries will make up more than half the projected population growth between now and 2050 The largest increases in population between 2019 and 2050 will take place in: India, Nigeria, Pakistan, the Democratic Republic of the Congo, Ethiopia, the United Republic of Tanzania, Indonesia, Egypt and the United States of America".

[2]The 39th edition of the IAEA report Energy, Electricity and Nuclear Power Estimates for the Period up to 2050.

**Table 19.1** World total and nuclear electrical generating capacity

| Electrical capacity | 2018 | 2030[a] | | 2040[a] | | 2050[a] | |
|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High |
| Total [GW(e)] | 7188 | 9782 | | 11,811 | | 13,633 | |
| Nuclear [GW(e)] | 396 | 366 | 496 | 353 | 628 | 371 | 715 |
| % of total | 5.5 | 3.7 | 5.1 | 3.0 | 5.3 | 2.7 | 5.2 |

[a]Nuclear capacity estimates take into account the scheduled retirement of older units at the end of their lifetime

**Table 19.2** World total and nuclear electrical production[a]

| Electrical production | 2018 | 2030 | | 2040 | | 2050 | |
|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High |
| Total (TW h) | 25,196 | 33,538 | | 41,101 | | 49,032 | |
| Nuclear (TW h) | 2563 | 2836 | 3844 | 2804 | 4977 | 2990 | 5761 |
| % of total | 10.2 | 8.5 | 11.5 | 6.8 | 12.1 | 6.1 | 11.7 |

[a]The nuclear production data presented in this table and the nuclear electrical generating capacity data presented in Table 19.1 cannot be used to calculate average annual capacity factors for nuclear plants as Table 19.1 presents year-end capacity

be matched equally by an increase in the capacity: there should be a slight decrease of the capacity in the low scenario (6%) but a large increase in the high scenario (80%). This is explained by performance gains. Given the expected retirement of older plants, this trend will undoubtedly equate with a significant number of new builts.

This is illustrated in the following Tables 19.1, 19.2 and 19.3.

More importantly for our discussion, this global growth is expected to go along with a new distribution of capacities worldwide. As evidenced in the tables below, there should be a decrease in Northern America and more significantly, a very sharp decrease in Europe (Northern, Western and Southern) and an increase in all other parts of the world, especially in China and India. Nuclear is predicted to develop in Africa, Latin America, Western, South eastern Asia, and southern Asia even in the high scenario in Oceania.

Although it would need a detailed analysis of the social, political, economic development prospects of all countries likely to embark into nuclear to assess the vulnerability of the non-proliferation regime in the future, the indication of the new distribution of nuclear worldwide already hints to some obvious challenges that will have to be overcome to maintain a high degree of confidence that the expansion of nuclear will not result in a higher proliferation threat.

*Changing technologies*—A vast majority of reactors in operation or under construction in the world are Pressurized water reactors (54 under construction) with rather large capacities mostly around 1000 MWe and up to 1600 MWe. There are also some Boiling Water reactors and fewer Heavy water reactors.

**Table 19.3** World nuclear electrical generating capacity, GW(e)

| Region | 2018 | 2030 | | 2040 | | 2050 | |
|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High |
| Northern America | 112.6 | 88 | 111 | 64 | 109 | 40 | 113 |
| Latin America and the Caribbean | 5.1 | 6 | 8 | 7 | 14 | 9 | 19 |
| Northern, Western and Southern Europe | 110.5 | 75 | 94 | 50 | 88 | 42 | 67 |
| Eastern Europe | 51.3 | 52 | 68 | 52 | 80 | 55 | 79 |
| Africa | 1.9 | 3 | 4 | 3 | 11 | 7 | 15 |
| Western Asia | 0.4 | 8 | 9 | 12 | 19 | 15 | 24 |
| Southern Asia | 8.5 | 19 | 27 | 32 | 47 | 51 | 84 |
| Central and Eastern Asia | 106.2 | 115 | 175 | 132 | 257 | 149 | 304 |
| South-Eastern Asia | | | | 1 | 3 | 3 | 8 |
| Oceania | | | | | | | 2 |
| World total | 396.4 | 366 | 496 | 353 | 628 | 371 | 715 |

These reactors will likely still be in operation in 2050 but many countries and industries are now working on advanced technologies aiming at smaller and sometimes modular reactors (averaging 300 MWe) based on a more diversified array of technologies (PWR but also environments or needs.

Fabrication technologies will also probably evolve as they do in other areas, using computerized support, using 3D printers for modelling and fabrication purposes, using new materials, and facilitating reproduction of parts and their assembly.

This may help in the production or replication area and represent an additional challenge for the detection of clandestine facilities.

*Matching the challenges*—To match the upcoming challenges and ensure the efficiency of the non-proliferation regime, policies and actions should be taken in the following areas to

- strengthen the legal/institutional framework
- review the fuel cycle arrangements
- make use of technology evolution
- consider emergency preparedness in the verification system.

*The legal/institutional framework*—The legal or institutional framework that was consolidated until the beginning of the Twenty-First Century with in particular the adoption of the Additional protocol, represents a solid basis that should not be fragilized by new and possibly attractive initiatives like the recent "Nuclear Ban Treaty".

Except for Israel, India and Pakistan that never signed the NPT, and Korea that stepped out, NPT is almost a universal Treaty and this is a major achievement.

However, the system would be strengthened by improving the decision-making process within the IAEA and at the UN level. When a case of violation is detected or even perhaps suspected, appropriate pre- defined actions should be quickly adopted by the international community. This kind of increased agility in reacting to any crisis will need leadership and increased cooperation. For instance, the possibility of retrieving specific nuclear material like HEU or under irradiated spent fuel could be devised as a means to gain time and de-escalate a proliferation attempt.

The universality of the adoption and implementation of Additional Protocols should be pursued.

Once this goal reached, a simplification and a merge of safeguards agreements and APs could facilitate their transparency and implementation.

In connection with the implementation of Additional Protocols and the increased number of countries and possibly less accessible locations where nuclear facilities will have to be safeguarded, the resources of the IAEA devoted to safeguards should keep pace with the growth of the nuclear fleet and be disconnected from the increase of the budget of the three other Departments. This will need political engagement to break the very politicized divide between "western countries" and the Group of 77, proponent of budget sharing. With the access to nuclear of new entrants, and developing countries, there should be some opportunities to have a more successful discussion on this aspect.

To meet the financial and more broadly the resource constraint, regional bodies like Euratom or ABACC could increase their contribution to the IAEA findings through joint inspections and sharing of equipment. They could for instance work under the IAEA responsibility in special cases when there is an urgent need to deploy inspectors to re-establish an inventory or carry out unexpected tasks following an agreement with a country where a situation has been detected. In the future such cooperation could be instituted in case North Korea was willing to get back into the international safeguards system.

In view of the future expansion of nuclear in other parts of the world could specific regional bodies similar to ABACC or using CoEs be in charge of some work and be in turn verified by the Agency?

Increased cooperation between NSG and IAEA could benefit both communities; the NSG could be more sensitized to weaknesses or difficulties in carrying out IAEA's inspection duties in some countries while IAEA would certainly benefit being informed of denials and of certain contracts.

Lastly, the IAEA should consider boosting existing regional offices or creating new offices in regions where nuclear energy is expanding (Asia) and promote training in national safeguards and security and in non-proliferation culture. This effort should not only address the future national Authorities but also the industry to stimulate exchange of good practices and raise awareness among the actors while promoting a better public acceptance of nuclear energy.

*Fuel cycle arrangements*—Back in 2005 the IAEA launched a wide-ranging reflection about a multinational approach to the fuel cycle.

Non-proliferation friendly nuclear production and trade or market rules could be devised.

In the perspective of increased quantities of fuel to be produced and then processed/stored worldwide, together with an increased number of countries with only one or a few power plants, new types of arrangements could be discussed.

The idea would not only be to minimize the number of locations where sensitive nuclear facilities could be localized but also under what kind of arrangements the security of supply to "dependent" States would be ensured.

Existing enrichment or reprocessing facilities should be first incorporated in such a network of "secured supply" and when located in NWS, should be subject to IAEA safeguards in perpetuity.

This kind of reflection would entail the participation of governments, industry, possibly NGOs and IGO like WTO.

Indeed, certain world trade regulations might have to be adapted to the needs of a specific nuclear market and elevate non-proliferation considerations as an absolute priority.

The innovative approach, foregoing the right to enrich and reprocess nuclear material that the Emirates agreed to follow in their bilateral agreement with the US was welcomed by many as a progress. Some argue that this should set the standard for any future agreement.

It remains to be seen if this one-sided commitment is the best way to address the non-proliferation concern.

As efficient and more equitable a scheme, might be that a real assurance of security of supply/treatment is given to the state unless such a State starts developing a capacity of its own.

*The technology evolution*—Although until now, the developments have occurred mainly with LWRs and rather with large and larger capacity reactors, the advent of smaller modular reactors or small and medium reactors (SMRs) and advanced technology systems (e.g. GEN IV) will mean new concepts and different fuel cycles to assess and to safeguards. A greater number of small facilities in different countries, sometimes difficult to access, or with specific features (e.g. the transportable nuclear power plants) will pose increased challenges in terms of resources for the IAEA but will also probably require developing new tools to facilitate safeguards.

An assessment of the safeguardability of three main types of advanced technology-fast reactors, triso fueled and molten salt fuel reactors—in comparison with safeguards applied to LWR was conducted by PGS and NEI[3] involving different experts. The report concluded that "all types of reactors presented specific challenges or weaknesses that might require to define a new safeguards approach or that could involve some changing in the design or the development of new tools to facilitate safeguards implementation."

Safeguards and security by design concepts will need to be implemented during the course of the conceptual phase of these new reactors.

The IAEA should ensure a very efficient technology watch on the general technology advances and be aware of likely advances that proliferators could use to serve their projects and defeat its strategy and current tools.

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[3]https://partnershipforglobalsecurity.org/advancing-nuclear-innovation/.

In addition, the IAEA should benefit from the use of novel technologies and keep developing specific equipment, like new detectors, sensors, cameras, trackers, and automated recognition devices that may increase its efficiency; new The use of specific robots, and why not drones to carry out inspections in remote areas should be envisaged.

This will need a legal frameworks and the acceptance of the country where those could be deployed but it could save human resources and be sent in case of emergency or social/political unrest.

A great attention should be devoted to the detection of tampering attempts, or to the cyber attacks on IAEA's and operators' data regarding safeguards and security aspects. Very robust, perhaps redundant systems should be adopted to ensure that no major damage could be inflicted to the IAEA's or the States and operators' barriers to proliferation.

*Emergency preparedness*—With the climate change phenomenon, natural events or catastrophes are predicted to be more intense and more frequent in the years to come. This will have undoubtedly, many geo-political, and economical consequences. It is predicted to affect more importantly developing regions of the world where nuclear is already expanding or will be deployed. It will certainly affect the security of nuclear facilities and require specific actions in terms of safeguards and non-proliferation.

What were the learnings from the Chernobyl nuclear accident and the consequences of the tsunami on the Fukushima power plant, from a safeguards point of view? How tools and strategies of the IAEA (i.e. the redundancy principle) are resistant enough or reactive enough to ensure that no diversion or theft has taken place during unprecedented, unexpected natural disasters? Should the IAEA perform its own "safeguards stress tests "or assessment of the emergency preparedness structure and needs for adapting the approaches and tools? Increased international cooperation and integration of such learnings in the future concepts might be taken into consideration.

*Conclusions*—If we look back at the history of nuclear development and nuclear non-proliferation, we can only agree that no system is perfect and complete when designed, that efficient systems can hardly be defined once and for all.

The system has shown a good capacity to react to crises and adapt to an evolving environment.

Recent critical situations have occurred, demonstrating the weaknesses of the regime. Because the political stability of the regime is fragile, because the stake is so high there is little choice but to preserve, and strengthen the system based on the international legal instruments, the NPT and related safeguards agreements.

Continuous improvement of the system, including through political commitments, early voluntary implementation of legally binding texts pending their entry into force, increasing international cooperation is the only way forward.

Involvement of all actors including industry and the civil society, and between sectors will be needed.

To stimulate this “leap forward” of the non- proliferation regime, determined State or group of influential States should take the leadership and propose a bolder, more visionary approach similar to that crafted after World War 2.

The shift from traditional nuclear countries to new comers, will be accompanied by the shift from historical Western/Japanese suppliers to China, Russia or Korea as main suppliers.

Indeed, western nuclear industry is nowadays in a difficult position for different reasons and might disappear (Westinghouse, Areva). This trend will only be accelerated if there is no or only a shrinking domestic demand and no financial scheme to support exports of nuclear facilities.

In this situation new alliances may need to emerge, international cooperation will be needed more than ever not only to adapt the system but more importantly to anticipate changes and be prepared in a timely manner.

# Part VI
# Perspectives on Nuclear Non-proliferation—2

# Chapter 20
# Introduction

**Steve Fetter**

In the second panel on Perspectives on Nuclear Non-Proliferation, experts from the Israeli government, a South Korean non-governmental organization, and Pugwash provided interesting and contrasting views on the role played by ambiguity in nuclear security and nonproliferation.

Israel maintains a policy of deliberate ambiguity concerning its nuclear weapons program. Although Israel is widely believed to maintain a substantial nuclear stockpile, it neither confirms nor denies the possession of nuclear weapons. Israel believes ambiguity is stabilizing because the likelihood that Israel has an unacknowledged nuclear arsenal serves as a potent deterrent, while avoiding the cascade of nuclear proliferation in the region that likely would result if an arsenal were acknowledged officially. Israel insists that it is fully committed to nonproliferation but cannot join the Non-Proliferation Treaty (NPT) because violations by Iraq, Libya, Syria, and Iran have demonstrated the inability of the NPT to prevent proliferation in the region. It also points to the use of chemical weapons by Syria and other countries as requiring a treaty that bans all weapons of mass destruction from the Middle East. In making these arguments, Israel does not acknowledge the role that its imputed nuclear weapons have played in stimulating interest in nuclear and other weapons of mass destruction by other countries in the region. There is increasing reason to question whether ambiguity is stabilizing. Iraq, Iran, and Syria did indeed pursue clandestine nuclear programs. Ambiguity has undermined Israel's position in international debate on nuclear security and nonproliferation. Israel has not signed the NPT and has generally linked this to progress on broader regional security issues and a durable peace settlement in the Middle East. David Nusbaum notes that past violations of the NPT by Iran, its failure to provide a full accounting of its nuclear weapon activities, and its acquisition and continued maintenance of relevant equipment and knowledge indicate that Iranian promises cannot be trusted and that Iran's nuclear program

S. Fetter (✉)
University of Maryland, College Park, MD, USA
e-mail: sfetter@umd.edu



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can be restored. But it would be difficult to argue that the region would be safer or more stable with the Joint Comprehensive Plan of Action in danger of dissolving completely. Nusbaum presents the Israeli position in its most cogent form.

Unlike Israel, North Korea visibly demonstrated its nuclear capability with a series of nuclear tests, including a high-yield explosion in September 2017 that North Korea claimed was a thermonuclear weapon. North Korea demonstrated the potential to deliver nuclear weapons with a series of missile tests, culminating in the November 2017 launch of a missile capable of reaching the continental United States. But a different kind of ambiguity is at play in the negotiations between the United States and North Korea. As Young-Ho Park notes, North Korea and the United States have both committed to "complete denuclearization of the Korean Peninsula," but they have different definitions of "denuclearization." The lack of specificity has enabled the parties to lower tensions, at least temporarily, and to claim they are working toward a common goal. But the same lack of a common definition and understanding will make progress difficult. Negotiated denuclearization is possible only if North Korea agrees to a definition close to that offered by the United States—in particular, to declare and verifiably dismantle all nuclear weapons and to declare and place under safeguards all nuclear materials and nuclear facilities. But Park argues that the North Korean government values its nuclear program more than it values the general welfare of its citizens, and for that reason it is unlikely to agree to true denuclearization. Park sees only two alternatives to negotiated denuclearization: forced denuclearization or living with a nuclear North Korea, neither of which is desirable.

Trust is the missing element for Middle-East peace, according to Paolo Cotta-Ramusino. Although the United States and Israel focus on Iran's nuclear program as the motivation for sanctions, it is clear that a broader distrust of and opposition to the Iranian government is the basis for their efforts to undermine the JCPOA. Cotta-Ramusino also notes that efforts in South Asia to eliminate ambiguity about the circumstances under which nuclear weapons would be used have laid the seeds for disaster. India has promised not to use nuclear weapons first but has pledged to retaliate massively to any nuclear attack on India, including on Indian forces. Pakistan has announced it would use nuclear weapons first to stop and repel an invasion by India, and to make this threat credible has developed and deployed a large number of tactical nuclear weapons for use against enemy forces on Pakistani soil. This is similar to NATO's plan during the Cold War for stopping a Soviet and Warsaw Pact invasion of Western Europe. A key difference is that Pakistan's faith that its nuclear arsenal would deter an Indian invasion has given it the confidence to support insurgents and other attacks against India. Pakistan could miscalculate, supporting or engaging in actions that India deems unacceptable threats to its national security that warrant a forceful military response; and India could miscalculate by responding in a manner forceful enough to threaten the security of Pakistan and prompt it to use nuclear weapons to stop India. It is not difficult to see how this could lead to rapid escalation and nuclear attacks and counterattacks that could kill hundreds of millions in the densely populated cities of South Asia.

# Chapter 21
# The Israeli Perspective on Nuclear Security, Nuclear Safety and Non-proliferation

**David Nusbaum**

*Israel and the Non-Proliferation Regime*—Israel is fully committed to non-proliferation of nuclear weapons, and to participation in international efforts to prevent their spread. Israel thus recognizes the value of the Non-Proliferation Treaty, and supported its adoption in 1968 in the UN General Assembly. However, a global regime like the NPT has limited relevance in the Middle East. Its weakness in the Middle East, has been demonstrated by four cases of violations of the Treaty's basic obligations, namely by Iraq, Libya, Syria and Iran. Syria's use of chemical weapons is a recent use by a Middle Eastern country of Weapons of Mass Destruction.

Based on the poor track record of NPT compliance in the region, Israel does not see NPT membership as a goal in and of itself, but rather, as potential means for enhancing security for all states. In this regard, Israel does not believe that NPT membership serves or would enhance its national security.

Israel's long held vision of a more secure and peaceful Middle East, requires that all regional states engage in a process in direct and sustained dialogue to address the broad range of regional security challenges in the Middle East.

Such a dialogue, based on the widely accepted principle of consensus, can only emanate from within the region, and address in an inclusive manner, the threat perceptions of all regional parties with a view to enhance and improve their security. Direct contact, combined with trust and confidence building, is an essential basis for the creation of a new security paradigm in a region that is increasingly fraught with wars, conflicts, disintegration of national territories and human suffering. However, this noble idea is unfortunately detached from the volatile regional realities.

It is clear that the prerequisite for regional discussions on establishment of a mutually, effectively, and verifiable zone free of Weapons of Mass Destruction (WMD), is mutual recognition. Mutual recognition do not currently exist in the Middle East, where the majority of Arab States, as well as the Islamic Republic of Iran, do not even

D. Nusbaum (✉)
Israel Atomic Energy Commission, Tel Aviv, Israel
e-mail: dnusbaum@iaec.gov.il



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recognize the existence of the State of Israel, and some even openly and explicitly threaten to destroy it.

Anti-Israel Initiatives, like the one in New York (November 2019), will only succeed in undermining the real regional security challenges, including those in the nonproliferation realm. Israel hope that the day would come where the Arab group will become interested in creating a constructive work plan to promote confidence and security in the region and not in singling out Israel and play into the hands of Iran.

*Israeli Perspective on the Non-Proliferation Challenges*—Israel cope with many non-proliferation challenges. The major challenge relates to Iran's persistent strategic aspirations to acquire nuclear weapons, coupled with it ballistic missile program, terror support, and destabilizing regional behavior.

Iran's threats to expand its nuclear program are a blatant attempt to extort the international community. The recent revelations of Iranian undeclared activities require a clear and collective message to be sent to Iran—the world will not accept Iran's continued reprehensible conduct in the nuclear realm.

The information revealed by Israel in the nuclear archive clearly proves that Iran continued its activities related to the development of a military nuclear weapons program. These activities included the protection, preservation and massive concealment of capabilities, information, undeclared activities and nuclear materials.

Iran continues to deceive the international community, while failing to provide clear and honest information regarding its nuclear program, as part of its CSA and safeguards commitments. These are not activities, which indicate a civilian nuclear program. These activities clearly indicate that a nuclear weapons program existed, is being maintained, and can be restored in the future.

The second challenge concerns Syria's nuclear program. This is an unfinished business, since the IAEA's investigation has never been exhausted due to lack of cooperation from Syria. As is well known, Syria built jointly with the DPRK a clandestine nuclear reactor, which was revealed and destroyed in 2007. Had this nuclear reactor been completed and operated, it would have been ideally-suited to produce plutonium for nuclear weapons purposes. Needless to say, the construction of such a reactor was done in blatant violation of Syria's NPT safeguards obligations, as it should have been declared to the IAEA.

The third non-proliferation challenge concerns potential proliferation from the DPRK to the Middle East. After its cooperation with Syria to build a secret nuclear reactor, Israel is concerned about future potential cooperation in the nuclear domain and other weapons of mass destruction with state and non-state actors in our region.

The forth challenge in Israel's perspective concerns nuclear energy in the Middle East. In recent years there is a growing interest in the construction of nuclear research and power reactors in our region. Israel does not object to the peaceful uses of nuclear energy in the Middle East, (conditioned upon):

- As long as its guaranteed exclusive use for peaceful purposes.
- Complete respect by countries that would like to embark on a nuclear energy program for relevant international non-proliferation obligations and commitments. Joining the Additional Protocol is a prerequisite for the supply of nuclear technology to new countries.
- Associated fuel cycle technologies, which are the proliferation risk, must be avoided. The suppliers should avoid the sale of any such technologies to new countries. Second, regional countries themselves must commit not to build or purchase such technologies as a condition for the supply of nuclear reactors.
- Certain nuclear reactors should be supplied as a "black box", according to the build-own-operate model. By certain reactors we mean those that are more proliferation resistant (light water, low enrichment fueled reactors). In order to sustain a black box model, the supplier has to guarantee a life-time fuel supply. It is also necessary to agree in advance on solutions for spent fuel take-back.
- Finally, the buyer country must commit to adopt and implement international standards for nuclear safety and security, including emergency preparedness and response.

One of the major non-proliferation challenge in Israel's view generally concerns the presence and active involvement of non-state actors in our region, which pose a potential nuclear security threat for the region. Non-state actors already pose a direct threat to Israel's national security, having been a victim of terrorist and rocket attacks against civilian population. Regional non-state actors enjoy state support as they are actively supported, funded and trained mainly by the Islamic Republic of Iran.

Additionally, they possess a large number of rockets and missiles, which cover the entire territory of the State of Israel. Non-state actors' interest in getting access to non-conventional weapons is a serious threat and challenge in Israel's view. For its part, Israel has taken comprehensive measures to reduce the risk of theft or sabotage in its nuclear centers, as well as radiological materials used in medicine, industry and other sectors.

*Israeli Perspective on Nuclear Security*—Today, more than ever, nuclear security and safety must be at the forefront of global concern. Threats to nuclear security and safety know no boundaries. In light of these destabilizing elements, we cannot ignore the repeated and explicit threats made by Iran and its proxies to attack Israel's nuclear sites.

These outrageous threats require Israel to take action and continue to protect and defend its nuclear facilities. These facilities are constantly upgraded and reinforced, in line with IAEA safety guidelines, in order to withstand any attack.

Israel strongly encourages regional cooperation in this context. Israel has repeatedly expressed its willingness to collaborate with all of its neighbors on safety and security issues. Israel is committed to act jointly with all states in its region for the shared goal of promoting and strengthening nuclear security. Israel supports the 2016 NSS Joint Statement on Sustaining Action to Strengthen Global Nuclear Security. We also joined the Nuclear Security Contact Group, aiming towards facilitating cooperation and engagement on nuclear security, following the conclusion of the NSS process.

A further key aspect of this goal is the development of technologies the make nuclear materials safer, and assists in responding to an incident of nuclear terrorism.

In this regard, Israel has established a national forensics laboratory, which takes part in the global effort to promote the science and applications of nuclear forensics. This laboratory collaborates with the parties to the Global Initiative to Combat Nuclear Terrorism. The Israel National Laboratory for Nuclear Forensics aims to assist in investigation of criminal events and emergencies involving radioactive or nuclear materials.

The laboratory uses a variety of techniques to characterize materials, including nuclear counting, analytical chemistry, radiation measurements, and various radiography techniques. The main roles of the laboratory are:

- Characterization of the radioactive or nuclear material in order to determine its production site, production date, intended use, and the route from production site to the crime scene;
- Assisting the police in handling "classic" forensic evidence contaminated with radioactive material;
- The laboratory operates in collaboration with the Division of Identification and Forensic Science (DIFS) of the Israel Police and with Israel's emergency response organizations, as well as with the world's leading nuclear forensic laboratories.

Israel is a country, which faces explicit terrorist threats, including the launching of rockets at its civilian population and nuclear research centers, is deeply aware of the threat of nuclear and radiological terrorism. Israel is ready to assist and contribute to any international effort to curtail it. Israel's highly developed technology, bilateral collaborations, and active participation in IAEA training and professional programs maintain Israel at the first line of defense against such threat.

Israel continues to follow closely IAEA guidance, regarding the security of nuclear facilities, and the protections of materials used in nuclear research and applications. Israel has ratified the 2005 Amendment to the Convention on the Physical Protection of Nuclear Materials (CPPNM), and has fulfilled its commitments, including the submission of a report on its national legislative implementation of the Convention, as required by Article 14. The international community can rest assure that Israel upholds the highest standard of physical protection measures in its nuclear centers, in accordance with international standards and obligations, as well as national legislation and best practices. Israel has also signed the International Convention for the Suppression of Acts of Nuclear Terrorism. Periodic national preparedness and response exercises are conducted, with the participation of international observers and partners.

Israel's national representatives regularly engaged in IAEA Incident and Emergency Center exercises. Moreover, Israel has joined the IAEA Response and Assistance Network as part of its commitment to global and regional collaboration. Israel continues to contribute both financially and in kind to the IAEA's Division of Nuclear Security, by providing radiation detector systems to IAEA member states.

*Israeli Perspective on Nuclear Safety*—An International Atomic Energy Agency (IAEA), Integrated Nuclear Safety Assessment of Research Reactors (INSARR), mission held in Israel few years ago. The purpose of the mission was to conduct a peer-review of the safety of the IRR-1 Reactor, located in the Soreq Nuclear Research Center (SNRC). The mission included IAEA safety experts as well as international experts in the field of nuclear safety from five countries. The INSARR is a peer review of the safety of research reactors that is conducted based on the IAEA safety standards. Israel's decision to invite the IAEA mission is part of international efforts, led by the IAEA, to study and apply the lessons learned from the March 2011 nuclear accident in Fukushima, Japan. The IAEA peer review team noted the strengthening of the national regulatory system to enhance independence and the efforts of the operator to enhance reactor safety. The team also noted areas of good practices and provided the Israel Atomic Energy Commission with recommendations and suggestions for further safety improvements. "By requesting this mission, Israel has made a strong statement about their commitment to nuclear safety and to continuous improvement," INSARR Team Leader, James Lyons, said.

Along with other IAEA Member States, the State of Israel dedicates considerable resources to upholding and strengthening nuclear safety. The Government of Israel affirmed the independent status of the Nuclear Licensing and Safety Office. Furthermore, Israel established a Nuclear Safety Committee, which is a public committee made up of former public figures and security, and reports directly and annually to the prime minister.

Israel also maintains cooperation with several leading countries in the field of nuclear safety. Israel is actively participate in four IAEA's safety standards committees: nuclear safety (NUSSC); radiation safety (RASSC); the safety of radioactive waste (WASSC); the safe transport of radioactive material (TRANSSC) and above all in the Commission on Safety Standards (CSS) which oversees the IAEA safety standards program.

Though it considers the chances for radiation emission from its nuclear centers as very low, Israel conducts national preparedness exercises and has put in place a contingency plan for such a scenario.

This article could not be completed without the quote from Salvador De Madariaga:

> The trouble with disarmament was (and still is) that the problem is tackling upside down and at the wrong end…Nations don't distrust each other because they are armed; they are armed because they distrust each other. And therefore to want disarmament before a minimum of common agreement on fundamentals is as absurd as to want people to go undressed in winter. Let the winter be warm, and they will undress readily enough without committees to tell them so.

# Chapter 22
# Options for Addressing the DPRK Nuclear Program

**Young-Ho Park**

*North Korea's Nuclear and Missile Capability*—Nuclear Capability:

- The DPRK conducted six times of nuclear test, including a thermonuclear weapon (hydrogen bomb) in September 2017.
- As of June 2019, it is estimated that North Korea has up to 30 nuclear warheads[1] (SIPRI) and sufficient fissile material[2] for an additional 30–60 nuclear weapons (Arms Control Association).
- It declared itself a globe-spanning nuclear weapons power on November 29, 2017 and insisted that the United States deal with it on those terms.

Missile Capability:

- The DPRK successfully launched an ICBM (Hwasong-15) from the vicinity of Pyongsong on November 28, 2017.
- U.S. Forces Korea acknowledges that North Korea's Hwasong-15 (ICBM) can hit targets anywhere in the United States, with an estimated range of nearly 13,000 km (8000 miles) (*2019 Strategic Digest*, USFK).
- North Korea carried out around 25 tests of ballistic missiles, including SLBM, IRBM, ICBM, since February 2017. Under Kim Jong-un,[3] more than 90 tests have been undertaken. Under water-platform launched ballistic missile—SLBM—aims to have a second strike capability.

[1] http://www.recna.nagasaki-u.ac.jp/recna/en-topics/22534.

[2] https://en.wikipedia.org/wiki/Fissile_material.

[3] https://en.wikipedia.org/wiki/Kim_Jong-un.

Y.-H. Park (✉)
Korea Institute for National Unification, Seoul, Republic of Korea
e-mail: kinupark@hanmail.net



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*Implications of North Korea as a 'Nuclear Weapons State'*—North Korea as a nuclear weapons state challenges international order in three respects.

- First, it is a significant challenge to the NPT regime centered on five nuclear-weapon powers (P5). If North Korea's development of nuclear weapons program cannot be controlled, stopped and finally eliminated, those states with the capacity to develop nuclear weapons, such as Japan and South Korea, may be tempted to become next nuclear aspirants.
- Second, it can bring about a structural change to the international security order in Northeast Asia. With US-China strategic collusion underway, this may lead to a reprise of the confrontation between naval and land-based powers that played out around the Korean peninsula during the Cold War. While no country in Northeast Asia accepts North Korea as a nuclear weapons state, strategic calculations are different from one another.
- Third, in terms of inter-Korean relations, under the UN and international sanction regime, South Korea's policy toward the North, putting priority on economic cooperation and exchanges, can hardly be implemented without North Korea's concrete actions toward complete denuclearization. While the Trump administration reiterates maintaining sanctions until risk from North Korea "substantially reduced", the Moon administration wants the US to ease sanctions.

As a nuclear state, the North Korean leadership began to display increased confidence in various areas.

- First, North Korean leader, Kim Jong-un, has confidence in the strength of grip on power and regime security. A powerful nuclear deterrent is Kim's most important tool for guaranteeing regime security as well as personal political survival.
- Second, the North Korean leadership believes they have secured a safety valve in terms of military and security strategy. North Korea can pursue self-reliant security strategy, tactics, and diplomacy against not only the U.S. but also China and Russia.
- Third, for North Korean dictator, nuclear weapons give him the means and the excuse to strengthen his basis of internal rule and exercise absolute control over the North Korean society.
- Fourth, North Korea can raise its voice that peace talks should be held to replace Armistice Agreement with a peace treaty between North Korea and the United States. Toward the U.S. it will grow bolder in its demand for security assurances as well as the withdrawal of U.S. troops and the breakup of the ROK-U.S. alliance.
- Finally, nuclear weapons enable North Korea to essentially use South Korea as a hostage in its foreign and inter-Korean policies. Since before the nuclear test, North Korea had argued that its "nuclear deterrent" would "protect peace and stability" not only for itself but for South Korea as well.

Kim Jong-un's goal: (1) secure his rule against internal challengers, (2) achieve and demonstrate a reliable nuclear deterrent, (3) improve his people's quality of life, and (4) elevate North Korea's international standing as a nuclear state.

*Contending Issues*—The Trump-Kim joint statement, on June 12, 2018, states that the two countries (1) commit to establish new US-DPRK relations, (2) will join the efforts to build a lasting and stable peace regime on the Korean Peninsula, and (3) the DPRK commits to work toward complete denuclearization of the Korean Peninsula.

Since June 2018 summit, there have been one more summit (Feb 2019, Hanoi) and one meeting (June 2019, Panmunjom DMZ) between Trump and Kim and several high- and working-level talks between the US and North Korea, but no specific agreement on denuclearization is achieved.

At the moment, there are fundamental differences between the US and North Korea in terms of definition, approach, and roadmap concerning 'complete denuclearization.'

*Meaning of denuclearization*—The US's definition (goal) is Final, Fully Verifiable Denuclearization (FFVD). It is denuclearization of North Korea. It means: North Korea is

- To halt the testing of nuclear weapons and launches of ballistic missiles.
- To permit U.S. and international technical experts' access to key WMD-related sites throughout the process.
- To declare and shut down all nuclear facilities.
- To completely dismantle and remove its nuclear weapons, delivery systems, facilities, and associated material with an agreed timeline.
- To provide a comprehensive declaration of its nuclear and ballistic missiles, as well as chemical and biological programs.
- To rejoin the Non-Proliferation Treaty (NPT).

*Joint Declaration on the Denuclearization of the Korean Peninsula of 1992*:

- "shall not test, manufacture, produce, receive, possess, store, deploy or use nuclear weapons."
- "shall not possess nuclear reprocessing and uranium enrichment facilities."

*9.19 Joint Statement of 2005*:

- "Abandoning all nuclear weapons and existing nuclear programs and returning to NPT and to IAEA safeguards."

North Korea has yet to provide its version of 'complete denuclearization' at the negotiation table. But DPRK government spokesman's statement on July 6, 2016, shows what it means by 'denuclearization,' that North Korea has long used. The statement says:

"The denuclearization being called for by the DPRK is the denuclearization of the whole Korean peninsula and this includes the dismantlement of nukes in South Korea and its vicinity." North Korea's specific conditions:

- First, all nuclear weapons of the United States must be publicly disclosed.
- Second, all the nuclear weapons and their bases should be dismantled and verified in the eyes of the world.

- Third, the U.S. should ensure that it would never bring again the nuclear strike means to South Korea and its vicinity.
- Fourth, it should commit itself to neither intimidating the DPRK with nuclear weapons nor using nuclear weapons against the DPRK in any case.
- Fifth, the withdrawal of the U.S. troops holding the right to use nuclear weapons from South Korea should be declared.

*Approach and Roadmap*—The US:

- US objective is ultimately the denuclearization of North Korea.
- US position: "Nothing is agreed to until everything is agreed to."
- The US doubts if North Korea has made a strategic choice to denuclearize. But the US believes there's a possibility that North Korea can make the choice to completely denuclearize.
- Before the completion of denuclearization process, the US wants to get the full extent of the North Korean WMD. In the process, North Korea is required to provide a comprehensive declaration at some point. The DPRK should allow expert access and monitoring mechanisms of key sites to international standards. And ultimately, the removal and destruction of stockpiles of fissile material, weapons, missiles, launchers, and other WMD.
- All of this must be addressed in a roadmap at the working-level negotiations. The roadmap also includes the transformation process of the US-North Korean relations and the establishment of a permanent peace on the Korean Peninsula.
- Once the definition and the roadmap are agreed, the implementation can be simultaneously and in parallel.

The DPRK:

- The DPRK regards powerful self-defense capacity as a cornerstone of the existence of a state/regime/one-man rule dictatorship and a guarantee for safeguarding peace.
- It demands that the ROK-US joint military exercises be stopped and the introduction of war equipment including strategic assets from outside completely be suspended.
- North Korea holds a step-by-step process. It does not offer its version of a roadmap to the final stage of denuclearization.
- North Korea is very reluctant to provide a full declaration that is necessary for the completion of the process of denuclearization. But the US wants that the full declaration will become well before the end.

It seems that while the US is prepared to negotiate concrete steps toward the final denuclearization along with those of the normalization of bilateral relationship and the signing of a peace treaty, the DPRK (Kim Jong-un) is not ready to make a strategic decision to give up nuclear weapons program.

*Options for Addressing the DPRK Nuclear Program*—Option 1—Negotiated Denuclearization, most desirable:

- The US and the DPRK agree on the definition of denuclearization and the end state and a roadmap to get to that end state.
- Denuclearization process goes along with steps toward normalization of relations and building of a permanent peace regime through a peace treaty.
- The completion of denuclearization comes along with the normalization of the US-DPRK relations and the establishment of a peace regime on the Korean Peninsula.

To get the negations to move on, the US and North Korea should take a step back from their respective 'excessive' demands and seek a stage-by-stage package deal to be followed by simultaneous actions.

There needs to be total agreement on what the end objective is, that is definition of denuclearization, and a roadmap to get to that end objective and working level meetings to unpack each of those elements.

Option 2—Forced Denuclearization:

While diplomatic approach, including negotiations, continues, UN and the US's sanctions and coercive diplomacy remain until Kim Jong-un makes a strategic decision to denuclearize.

- To put in place a punishing set of sanctions that can create every incentive for the North Korean leadership themselves to make right choices.
- But, military option is not preferable; seeking of regime change in the DPRK is not an option.
- The effect of economic sanctions and diplomatic coercion.
- Internal political change, including a new leadership.
- Policy changes, including the top decision-maker's thinking, to re-engage with the international community and the US in particular.

Option 3—Living with nuclear North Korea, undesirable:

- Negotiations are protracted.
- A nuclear North Korea is tacitly and implicitly accepted.
- Coexist with a nuclear North Korea while South Korea fall under North Korea's nuclear blackmail.
- It is highly likely that growing emerge to go nuclear in Japan and South Korea.

# Chapter 23
# Regional Rivalries and Their Implications for the Security and Nuclear Non-proliferation Regimes

**Paolo Cotta-Ramusino**

In this note I will consider two regions where the risks of nuclear proliferation and of possible nuclear use are particularly relevant. These two regions are the Middle East and South Asia. I would not discuss here the situation of North East Asia and the crisis of the US-Russia arms control regime, that are also a very relevant part of a global "nuclear" picture, that is worrisome on many aspects. Also I need to add that the nuclear problems are themselves part of a global situation where conflicts, antagonistic attitude, economic warfare and internal unrests are very much on the rise. Some remarks have been added here about the wars that are affecting in particular the Middle East. These are not easy times.

*Risks of Nuclear Proliferation coupled with instability and wars in the Middle East*—The discussion about eliminating the presence of nuclear weapons in the Middle East, as well as the possibility of introducing new ones, has been going on for about five decades. In 1974 Iran and Egypt proposed to create a nuclear weapons free zone in the Middle East. In 1995 the Review and Extension Conference of the NPT "noting the danger of nuclear proliferation, especially in areas of tension" declared to "endorse the aims and objectives of the Middle East peace process and recognizes that efforts in this regard, as well as other efforts, contribute to, inter alia, a Middle East zone free of nuclear weapons as well as other weapons of mass destruction".[1] The above declaration was a key element that guaranteed the approval of the indefinite extension of the NPT in 1995.

In the conclusions of the 2010 NPT review conference, it is stated that "The Secretary-General of the United Nations and the co-sponsors of the 1995 Resolution, in consultation with the States of the region, will convene a conference in 2012, to be attended by all States of the Middle East, on the establishment of a Middle East zone

[1]Resolution on the Middle East (1995 NPT Review Conference).

P. Cotta-Ramusino (✉)
Pugwash Conferences on Science and World Affairs, Rome, Italy
e-mail: paolo.cotta@mi.infn.it



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free of nuclear weapons and all other weapons of mass destruction, on the basis of arrangements freely arrived at by the States of the region, and with the full support and engagement of the nuclear-weapon States. The 2012 Conference shall take as its terms of reference the 1995 Resolution". We all know that this conference was never convened in 2012 or in the following years.

Israel is, up to now, the only Middle Eastern state that possesses nuclear weapons. Israel is of course not a member of the NPT. Israel, while refusing to participate in the proposed 2012 conference (or in any similar initiative[2]), stressed the fact that the elimination of nuclear weapons from the region should not be disconnected form a general discussion about enforcing or strengthening the general security of the region. Yet, a lasting security for all in the Middle East cannot be achieved without the resolution of the Palestinian issue, and Israel refuses the two-state solution or any meaningful accommodation with the Palestinians.

The questions we would like to ask here are: (1) Has the risk of nuclear proliferation in the Middle East been reduced? (2) Has the general security of the region improved? (3) Are nuclear risks in the (extended) region decreasing? I am afraid that the answers to these questions are in general negative. And unless some steps are taken to pacify the situation, the dangers will increase possibly to a critical level.

*Present risks of nuclear proliferation in the Middle East*—Let us start with the Iranian nuclear deal a.k.a. the JCPOA (Joint Comprehensive Plan of Action). It was an excellent deal as it was putting all nuclear activities of Iran under close scrutiny of the IAEA. And this was the most important element. Moreover, it was limiting the level of enrichment of Uranium, the production of Plutonium in heavy water nuclear reactor(s), the number and the efficiency of centrifuges, forbidding reprocessing, etc. Iran was subjected to many constraints that are not applied to any other country, that has a peaceful nuclear energy program. Iran accepted these very severe constraints, in exchange for the removal of the sanctions and the access to the financial and commercial international market that would be very important in promoting economic development. Iran, in particular, was and is interested in selling oil. When President Trump decided to abandon the JCPOA and to reinstate the full array of sanctions, this created a chain reaction that lead to the impossibility for Iran to have a sanction-free environment, even though all other signatories of the JCPOA, but the US, did not formally abandon the agreement. The key issue was of course the problem of secondary sanctions imposed by the US on companies and entities that did not abide by the US sanction regime. The EU tried to create a mechanism (INSTEX) that in principle could allow to preservation of economic interactions with Iran, despite the US sanctions. But as the Iranians clearly pointed out, up to now, there is "no money in INSTEX", the list of goods that can be exchanged with Iran is limited, export of Iranian oil is not guaranteed by INSTEX, and so on. The present Iranian Government, that supported the JCPOA, has not been able to deliver the result of opening Iran economically and financially to the outside world. And this has been visibly noticed by the more conservative opponents to the present government. The consequence of the sanctions on the quality of life of the Iranian people is

[2]The last of these initiatives has been the Conference held at the UN in New York (November 2019).

severe, as it has been shown recently by the popular revolts that happened after the doubling of the price of gasoline. Hence other sectors of the Iranian leadership may be interested in promoting a more aggressive attitude towards that part of the international community that is pressuring Iran, despite the "good will" showed by Iran in accepting the JCPOA. One year after the US exiting from the JCPOA, Iran decided to increase slightly the level of enrichment allowed by the JCPOA (from 3.67 to 5%) and to keep in Iran a larger quantity of enriched uranium. This has been a clear message that Iran wanted to convey to the signatories of the JCPOA. It should be noted that paragraph 36 and 37 of the JCPOA recognizes the right of Iran to exceed the limit set by the JCPOA itself, if the sanction system will not be eliminated or reduced as stated in the JCPOA. As the Iranians clarified openly, this exceeding the limits set by the JCPOA, is fully reversible if the European (and the other) countries that are still member of the JCPOA, will help maintaining the economic and financial opening with Iran. Otherwise other steps in the nuclear area could be taken by Iran. This may increase the possibility of Iran acquiring an effective military nuclear capability. At this point, other countries inside or outside the region can decide to attack the places of Iranian nuclear activities, generating a conflict with possibly very severe consequences. Finally, the possibility of Iran exiting the JCPOA and even the NPT itself is somehow discussed in Tehran and should not be considered as an empty threat. Although, Iran has stated on several occasions that it is committed to the Fatwa forbidding acquisition and use of nuclear weapons, it has to be seen what will happen in the future if the threats against Iran keep increasing.

Other countries in the region are developing (civilian) nuclear energy programs. Of course, we know that access to civilian nuclear energy is an "inalienable right" for all the NPT countries. The problem arises when, as in the case of Saudi Arabia, the country does not accept the additional protocol with the IAEA and does not accept any specific limits to its nuclear activities. We all know that there is no clear-cut distinction between civilian and military nuclear programs. The key issues are the level of enrichment and, mainly, the international control over nuclear activities (by IAEA). Setting a system of centrifuges that can perform any required tasks maybe not easy. But if one combines instruments provided by some states with some technical (engineering) assistance provided by other nations (such as Pakistan e.g. as far as this region is concerned), then the result in terms of risks of proliferation can be serious. Saudi Arabia said very clearly that if Iran develop a military nuclear capability, they will do the same. The US has announced that it is willing to help the Saudi (civilian) nuclear efforts. Hence the risks of further nuclear proliferation in the region of conflicts not to be underestimated.

All in all we can safely say that, under the Trump presidency, the U.S. has stimulated in various ways the possible nuclear proliferation in the Middle East, by killing the JCPOA, by supporting other countries that are planning to develop nuclear activities and by keeping refraining from pressuring Israel to participate to the meetings addressing the issue of a Middle Eastern zone free of Weapons of Mass Destruction.

As far as other Weapons of Mass destructions are concerned, notice that the Middle East is the only region that, in recent times, saw the systematic use of chemical weapons (in Syria, Iraq, and Iran) and this is far from being reassuring.

*Increasing tensions and instability in the Middle East*—The Israeli-Palestinian antagonism reached recently new heights. Abu Mazen suspended all existing agreements with Israel. The situation in Gaza is catastrophic for the civilian as it has always been in the last ten years: Gaza is like a large prison camp where we had thousands of civilian deaths and the large-scale destruction of the civilian infrastructure. Israel declared that the settlements in Palestine should be part of Israel. Moreover Trump declared that Jerusalem should be the location of the US Embassy.

The war in Syria, that caused up to now more than 400,000 deaths, is far from being over despite the collapse of ISIS in both Syria and Iraq. ISIS has been organizationally supported by some rich donors possibly in the Wahabi communities. The US withdrew its troops by leaving the Kurds at the mercy of Turkey.

The Yemen war that caused the direct death of about 18,000 civilians, while the number of deaths including the effect of famine can be in the order of magnitude of 100,000.

The civil war in Libya between the Haftar and Al Sarraj camps is likely not going to end soon.

In all these wars, we have seen the participation in various ways of different countries in and outside the region: Russia, Iran and Turkey operate in Syria; the Saudi and the Emirates[3] supported the attacks on the Houthis in Yemen who are in turn supported by the Iranians; the Saudis supported the military coup against the Government of the Muslim Brotherhood in Egypt; the Saudis, Emirates, Egypt are supporting Haftar in Libya while UN recognized Al Sarraj government, etc.

Moreover, there is a general hostility between the different branches of the Muslim religion: Shias against Sunnis, Alawites against Sunni, Zahidis in Yemen against Sunnis. The Sunni Shia antagonism is particularly visible in the relations between Iran and Saudi Arabia, but also affects Lebanon, Bahrain and Syria as well (in Syria the Alawites are considered de facto close to the Shias). But this sectarian infight affects also the internal climate of several countries, including Iraq, Saudi Arabia, Pakistan, Afghanistan and some central Asian republics. The slaughtering of the Yazidi should also be mentioned when talking about religious antagonism.

In all the region the term "terrorists" is used in a sectarian and instrumental way: the antagonists often accuse their opponents of "supporting terrorism". Even Qatar has been accused of supporting terrorism by Saudi Arabia and the U.A.E.

Moreover, the collapse of the JCPOA has induced hostilities among different oil producers. If Iran is forbidden to sell oil and send around oil tankers, then Iran will try to do its best to block oil tankers belonging to other countries in the Hormuz strait in particular.

In conclusion there is hardly a region in the world where antagonism, sectarianism and hostility are larger than in the (extended) Middle East.

*Nuclear risks and tensions in South Asia*—India and Pakistan are antagonistic countries that possess significant arsenals of nuclear weapons (about 140–150 each). The situation in this (extended) region can evolve easily in a catastrophic way. For instance if there is a serious "terrorist attack" in India, and India believes that Pakistan

[3]Fortunately, just recently the Emirates stopped to support the military activities in Yemen.

has organized it, then India will likely attack Pakistan with conventional weapons, and Pakistan, that is largely inferior to India in terms of conventional weapons, is in principle oriented to use tactical nuclear weapons in response to a conventional Indian attack.

Things changed for the worse on Aug. 5th, 2019. On that date the Indian Government obtained from the Parliament the removal of all the specific regional autonomy laws for the Jammu and Kashmir state. The valley of Kashmir, where Muslims are the large majority, has been isolated from the rest of India. As we speak now, it is forbidden for normal citizens or foreigners to go to the Kashmir valley. Political leaders of Kashmir are either in jail or under house arrest. This applies also to the former "chief ministers" of the state of Jammu and Kashmir (Mehbooba Mufti and Omar Abdullah) who were democratically elected and who are under house arrest without being accused of any crime. The people in general in the Kashmir valley have been under extreme pressure: they have been repressed politically, they lack jobs, the economy of the valley without visitors and tourists being allowed to come and is under severe strain. In conclusion the internal problems for the Indian State of Jammu and Kashmir are extreme. The Kashmiris who leave in Pakistan are of course sympathetic to the Kashmiris who live in India. Some of the groups of Kashmiri supporters from Pakistan may very well attack the Indian military in the Indian Kashmir. This can happen very well without direct or indirect intervention from the Pakistani State or its structures (like the Secret services known as ISI). But it is in the Indian interest to portray all possible troubles as the result of Pakistani malicious intervention.

In this way the tension between India and Pakistan increases. Any serious attack against Indian structures can be ascribed to Pakistan. If a serious attack happens in India, India's strategy is to occupy militarily the part of Pakistan where the attack has been supposedly originated. Pakistan strategy, in the case of a serious Indian conventional attack, is reportedly, to use tactical nuclear weapons against India. And this will start a nuclear war. Notice that the Pakistani strategy is in fact similar to the NATO strategy during the cold war, when NATO and the US were planning to use tactical nuclear weapons to compensate a conventional inferiority vis a vis the Warsaw Pact.

As a final remark we should notice that the Indian minister of defense has declared that India should abandon its nuclear no-firs-use policy, lowering further the nuclear threshold.

*What could be done?*—There is of course no easy recipe for a solution to the severe problems we have just mentioned. Few points should be nevertheless be highlighted. The international community should work seriously to calm down the difficult situations in the Middle East and in South Asia. In particular the international community should work in order to

- Restore the substance of the Iran nuclear agreement and guarantee that the respect of the JCPOA will yield Iran's access to the financial and commercial world market.

- Refrain from granting international support to local nuclear programs, unless the IAEA will be able to fully supervise the programs (incl. the additional protocol) and reasonable limitations to the programs will be set.
- Promote international dialogue and cooperation among the Middle eastern countries with the aim of achieving a reciprocal understanding and the limitation of hostile activities.
- Guarantee the freedom of movement of people and goods in the region to the maximum possible extent.
- Promote the end of conflicts in Syria, Yemen and Libya.
- Operate in order to restart the Israeli-Palestinian dialogue.
- Promote India-Pakistan dialogue with the aim of preventing nuclear use.
- Pressure India in order to reduce the political tension in the State of Jammu and Kashmir and make again the State open to Indian nationals and Foreign visitors as it was before.
- Induce India to free the political leaders who have not been accused of any wrong doing.
- Induce India and Pakistan to put back in place the aerial communications between the two countries. Bring back the road communications between the two countries and particularly the communications across the line of control in the Kashmiri region.

# Part VII
# International Technical Cooperation and the Role of Science Diplomacy

# Chapter 24
# Introduction

**Micah Lowenthal**

One way to understand the range or breadth of roles is to use the taxonomy articulated in the Royal Society and American Association for the Advancement of Science (AAAS) report New Frontiers in Science Diplomacy (2010):[1] Diplomacy for science is what we call international relations that facilitate cooperation on science. Science for diplomacy is where technical cooperation helps international relations by connecting people and providing an example of mutually beneficial cooperation. The collateral benefits of those interactions are relationships and better understanding of underlying culture, which is acquired only through interaction. And the third type, science in diplomacy is where scientists use information and analyses to address diplomatic issues. In a sense, the scientist-to-scientist engagements on security issues embodied by the Amaldi Conferences combine science for diplomacy and science in diplomacy.

Three organizations illustrate some of these roles of scientists in addressing problems between and among nations. The Nobel Peace Prize winning International Campaign to Abolish Nuclear Weapons (ICAN) has brought new energy and new people, including scientists, to the disarmament effort. The International Organization of the International Thermonuclear Experimental Reactor (ITER), a joint project of 35 nations to build the world's largest magnetic fusion energy facility, was born out of the Cold War. The Laser Interferometry Gravitational Observatory (LIGO), which detected gravitational waves directly for the first time in September 2015, draws members from across the United States and the world.

Scientists developed nuclear weapons and, because of that role, according to Alicia Sanders-Zakre, they had a sense of responsibility for controlling nuclear weapons.

[1] The Royal Society and AAAS [1].

M. Lowenthal (✉)
National Academy of Sciences, Washington, DC, USA
e-mail: mlowenth@nas.edu



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The organizations founded by scientists illustrate this history, including the Federation of Atomic Scientists (later the Federation of American Scientists), the Bulletin on of Atomic Scientists, the Union of Concerned Scientists, the Russell-Einstein manifesto and Pugwash, and others. Scientists continue to research and share their findings on the terrible consequences of nuclear war, including recent analyses of the effect of a limited nuclear exchange on the climate. ICAN has engaged scientists in support of the Treaty on the Prohibition of Nuclear Weapons (TPNW). Some working within the nonproliferation regime criticize the TPNW as counterproductive, redundant to and therefore distracting from the Nuclear Non-proliferation Treaty (NPT), and providing no path to arms reductions and disarmament. ICAN sees the TPNW as complementing the NPT, not interfering with it, but also not accepting the inaction on disarmament, and therefore inspiring scientists and others to develop frameworks for disarmament. ICAN utilizes the strength of youthful impatience and impertinence to speak up when told to be quiet, evident in other major social movements such as the current push for action on climate change.

Born of a desire to use science to demonstrate cooperation between rivals, the agreement to pursue ITER was a product of the 1985 Geneva summit between U.S. and Soviet leaders, a kind of multilateral descendent of the Soyuz-Apollo mission. Fusion is often touted as a future limitless energy source. ITER is the world's largest effort to bring that future nearer, and it illustrates how difficult practical international cooperation is. As Sergio Orlandi explained, ITER grew to have many partners and, through a selection process, the facility was located in Southern France. The partners provide in-kind contributions, such as the magnets, the vacuum vessel, and the cryoplant. It has been an enormous challenge as an engineering project to marry together these essential components from so many different places. There have also been considerations of export controls and security restrictions of the host country with respect to tritium. Rules enable these partners to make progress and, we hope for the benefit of humankind, succeed.

Barry Barish shared the 2018 Nobel Prize in Physics for "for decisive contributions to the LIGO detector and the observation of gravitational waves." This set of observations in 2015, verifying Einstein's 1916 prediction of gravity waves, is one of the great successes of modern physics and was achieved with participation of an international team, despite being located in the United States. Barish argues that cooperation among scientists in different countries is essential. Science is an international sport, trying to solve problems that do not yet have solutions. In LIGO, because the solutions were unknown, the project had to be organized and operated in a less hierarchical way than say a project to build a bridge with a known design. They came together and worked on a common problem and successfully developed solutions, which should give us hope for how scientists can help solve other problems.

Although these experts are optimistic about the potential for scientific cooperation to help the world avoid calamity, several concerns were raised. First, as valuable as international science institutions are for Science Diplomacy, a participant argued that their impact on real-world problems would be higher if the institutions would develop positions on issues for humankind. Dual-use technology, that is to say technology that has both benign and potentially harmful uses, is another concern. For example, if scientific results are openly available, then they could be misused. On the other side of that coin, are concerns about the securitization of science. According to Dr. Barish, scientists worry about these issues, not so much for the scientific results, but more for the new technologies used to reach those results. Pure science has to be open; this is a core principle. But the new technologies developed, such as artificial intelligence used for LIGO, raise several concerns about misuse. The scientists worry about that and are talking about it, but they have no solutions yet. For ITER, sensitive technologies are produced and controlled by the host country and not all partners and participants get access to the knowledge. A different kind of concern closed the session. The average age of scientists addressing nuclear issues has been rising for many years. ICAN has been effective in engaging young people around the world by having a simple, clear message on an important issue. It is easily understood and people are inspired to work on it.

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# Chapter 25
# Engaging Scientists Citizens, and International Youth in Diplomacy to Abolish Nuclear Weapons

**Alicia Sanders-Zakre**

The role of scientists, citizens and international youth in abolishing nuclear weapons is a topic that the International Campaign to Abolish Nuclear Weapons knows quite a lot about. As a campaign of over 500 partner organizations in over 100 countries, we bring together scientists and activists and citizens of all ages in pursuit of one common goal—banning and eliminating nuclear weapons.

I have great respect for the historic contributions of scientists to educate the public on the dangers posed by nuclear weapons and to press for nuclear abolition.

Scientific involvement in nuclear disarmament activism is not new—in fact it is nearly as old as the bomb itself. Many of the original scientists who developed the first nuclear weapons during the Manhattan Project later renounced nuclear weapons and began to advocate for their total and complete elimination.

Before the bomb was even dropped on Hiroshima, scientists were concerned about possessing and using this new weapon of mass destruction. Seventy scientists who worked on the Manhattan Project signed a petition drafted by Leo Szilard in July 1945 to express concern about the moral responsibilities of possessing nuclear weapons.[1]

In 1946, Leo Szilard and Albert Einstein created the Emergency Committee of the Atomic Scientists to warn the public about the danger of nuclear weapons.

In an initial fundraising letter for the committee in December 1946, Einstein wrote: "We scientists recognize our inescapable responsibility to carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications for society. In this lies our only security and our only hope—we believe that an informed citizenry will act for life and not for death."[2]

[1] "A Petition to the President of the United States," July 17, 1945, https://www.atomicheritage.org/sites/default/files/B04_03-03_01.jpg.

[2] Letter: Emergency Committee of the Atomic Scientists, December 11, 1946.

A. Sanders-Zakre (✉)
International Campaign to Abolish Nuclear Weapons, Geneva, Switzerland
e-mail: alicia@icanw.org



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Other scientists took up the call and formed organizations that still exist today to raise awareness of the dangers of nuclear weapons.

The Bulletin of the Atomic Scientists was first founded in 1945 by Manhattan Project scientists who could not remain aloof to the consequences of their work and continues to exist today as a platform for scientists, policy makers and activists to speak out about nuclear weapons risks and consequences.

Einstein and others formed Pugwash Conferences on Science and World Affairs in 1955 to draw attention to the dangers of thermonuclear weapons and the need to peacefully resolve conflicts.

The Union of Concerned Scientists was formed in 1968 "to express determined opposition to ill-advised and hazardous projects such as the ABM system, the enlargement of our nuclear arsenal, and the development of chemical and biological weapons."[3]

In addition to forming organizations, individual scientists, including physicians and climate scientists documented the catastrophic humanitarian and environmental consequences of nuclear weapons use by publishing articles and speaking out.

Soviet physicist Andrei Sakharov, who worked on Soviet thermonuclear weapons, began publishing articles in the 1950s on the hazards of radioactive fallout, while pushing Soviet officials to stop atmospheric testing.

Dr. Helen Caldicott used her scientific expertise and concern about the medical effects of radioactive fallout to form Physicians for Social Responsibility and mobilize a mass movement to freeze the nuclear arms race in the 1980s. In large part due to her efforts, one million people rallied in New York City in 1982 to call for a nuclear freeze.

In the early 1980s, astrophysicist Carl Sagan also began to warn the public about "nuclear winter"—the terrifying long-term consequences of nuclear war that could lead to global famine and starvation.

Updated studies on nuclear winter indicate that the consequences could be even more devastating than previously expected. An updated climate modelling study from Owen B. Toon and nine other leading researchers was published on 2 October 2019. It shows that a relatively limited nuclear exchange involving 250 nuclear weapons dropped on urban areas in India and Pakistan would result in dramatically reduced sunlight, precipitation and global cooling—choking off food production as we know it for the next decade at least.[4] Beyond the unacceptable immediate deaths, billions could die from the resulting famine in the long term.[5]

Nuclear weapons aren't just city destroyers, they could be humanity destroyers. We cannot wait to act.

Many scientists today recognize the growing risks nuclear weapons pose and are following in the footsteps of their predecessors to call for nuclear weapon abolition.

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[3] "Founding Document: 1968 MIT Faculty Statement," Union of Concerned Scientists, https://www.ucsusa.org/about/history/founding-document-1968-mit-faculty-statement.

[4] Toon et al. [1].

[5] Helfand [2].

In July 2017, over 3700 scientists from around the world signed a letter in support of the negotiations of the Treaty on the Prohibition of Nuclear Weapons, urging their national governments to support the treaty as well.

They wrote: “Scientists bear a special responsibility for Nuclear Weapons, since it was scientists who invented them and discovered that their effects are even more horrific than first thought.”[6]

The letter was organized by Max Tegmark, a physics professor from the Massachusetts Institute of Technology and included Stephen Hawking and 27 other Nobel Laureates in Chemistry, Physics and Physiology and Medicine, including two individuals who won Nobel Prizes in two disciplines. Former U.S. Secretary of Defense William Perry also signed the letter.

The over 3700 scientists got their wish—in July 2017, 122 countries voted to adopt the Treaty on the Prohibition of Nuclear Weapons. 79 countries have signed the treaty and 32 have ratified it—over half of the required 50 ratifications for it to enter into force.

The treaty prohibits states-parties from developing, testing, producing, manufacturing, transferring, possessing, stockpiling, using or threatening to use nuclear weapons, or allowing nuclear weapons to be stationed on their territory. It also prohibits them from assisting, encouraging or inducing anyone to engage in any of these activities. According to research from the Norwegian People’s Aid, 155 number of states currently maintain policies and practices that are compliant with these prohibitions.[7]

It includes positive obligations for states to provide victim assistance and environmental remediation for people and places harmed by nuclear weapons use and testing.

The treaty requires that all countries have a Comprehensive Safeguards Agreement with the International Atomic Energy Agency as a *minimum*, just like the Nuclear Non-Proliferation Treaty. However, the TPNW goes a step further than the NPT on safeguards. Unlike the NPT, the TPNW actually *requires* the Additional Protocol for states that already had one in force at the time of the treaty’s entry into force.[8]

Scientists played a key role during the negotiations of the TPNW and continue to do so as the treaty nears entry into force. A team of Princeton University physicists and political scientists published a paper outlining a possible structure for negotiating and verifying the irreversible elimination of nuclear weapons if a nuclear armed state joins the TPNW.[9]

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[6]“An Open Letter From Scientists In Support of the UN Nuclear Weapons Negotiations,” Future of Life Institute, https://futureoflife.org/nuclear-open-letter/.

[7]Norwegian People’s Aid, “Nuclear Weapons Ban Monitor 2019, October 2019, https://banmonitor.org/.

[8]See Article 3: “Each State Party to which Article 4, paragraph 1 or 2, does not apply shall, at a minimum, maintain its International Atomic Energy Agency safeguards obligations in force at the time of entry into force of this Treaty, without prejudice to any additional relevant instruments that it may adopt in the future.”

[9]Patton et al. [3].

And ICAN is currently working with scientists and researchers to better understand and educate the public on the increasing nuclear weapons risks caused by emerging technologies like artificial intelligence and cyber technologies.

Scientists have been instrumental in educating the public on nuclear weapons dangers and the need for nuclear abolition. But they need a mobilized public—and engaged young people in particular—to transform their warnings into real change.

Luckily, there is a new generation of young people who refuse to accept the failure of adults to take action on existential threats to their future.

16 year old Greta Thunberg, whose simple act last year of refusing to go to school to protest political inaction on climate change, has spread into a global movement.

One of Greta's strengths is youthful impatience. Impatience to demand that change happens now and impertinence to speak up for values even when others tell her to be quiet.

We need to all be impatient when it comes to these existential threats, including nuclear weapons. We can't afford to wait.

Greta was sick of waiting for powerful people to solve climate change. She was sick of inaction and excuses, as minute by minute we track closer to armageddon. So she took power into her own hands.

Like with climate change, scientists have warned that nuclear weapons threaten the future that young people will inherit.

Like with climate change, the reality of nuclear weapons caused a global response of denial. Seven decades of denying that these weapons have to be eliminated as a matter of urgency. We must destroy them, before they destroy us.

Martin Luther King, Jr. eloquently explained while accepting the Nobel Peace Prize.

He said, "The fact that most of the time human beings put the truth about the nature and risks of the nuclear war out of their minds is because it is too painful and therefore not acceptable does not alter the nature and risks of such war. The device of "rejection" may temporarily cover up anxiety, but it does not bestow peace of mind and emotional security."[10]

Young people are sick of inaction on nuclear disarmament, like Greta is sick of inaction on climate change. Grassroots pressure is bringing democracy to nuclear disarmament in a movement spearheaded by young people, bold female politicians, diplomats and municipalities, and grounded in the leadership and moral authority of the survivors of nuclear bombings and testing.

ICAN is full of young people around the world like Greta. Just look at our international staff team. When we won the Nobel Peace Prize in 2017, none of our staff members were over the age of 35. Our campaigners around the world are young and passionate activists, who like Greta, are taking their future into their own hands.

We are helping to educate more young people about the threat of nuclear weapons by bringing young people to Hiroshima for an intensive course to learn first-hand about the terrible effects of nuclear weapons. This summer, through fieldwork and

[10]"Martin Luther King Jr.—Acceptance Speech," December 10, 1964, https://www.nobelprize.org/prizes/peace/1964/king/26142-martin-luther-king-jr-acceptance-speech-1964/.

lectures the participants learned about the humanitarian impacts of nuclear weapons, global trends on nuclear weapons and met with UN officials, diplomats, and civil society members.

One of our partner organizations, Peace Boat, has connected over 100 hibakusha, the survivors of the bombings of Hiroshima and Nagasaki, with hundreds of young people to ensure that their stories are passed on and the humanitarian impact of nuclear weapon use is not forgotten.

We are also shedding light on the links between universities and the nuclear weapons complex in the United States, so that students can decide if they want their university to continue to contribute to developing weapons of mass murder.

An ICAN report documents how U.S. universities have been involved in research about and production of nuclear weapons since the Manhattan Project through direct lab management, institutional partnerships and research and training programs for students to become nuclear weapons scientists.

We call on universities to provide greater transparency about their links to nuclear weapons research and production, dissolve partnerships with nuclear weapons production sites and contracts directly related to nuclear weapons and reinvest weapons activities funding to non-proliferation and environmental remediation efforts.

In conclusion, the nuclear abolition movement owes much to scientists, who have spoken out about the medical and environmental hazards of nuclear weapons and have called for their elimination. As a network of young activists, ICAN works to amplify the concerns and follow the advice of these scientists who demand a world free of nuclear weapons.

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# Chapter 26
# ITER Project: International Cooperation and Energy Investment

**Sergio Orlandi**

*General Overview*—The ITER project, established by an international agreement among seven Members (China, the European Union, India, Japan, Korea, the Russian Federation and the United States of America) Fig. 26.1, is a critical step in the development of fusion energy: its role is to confirm the feasibility of exploiting magnetic confinement fusion for the production of energy for peaceful purposes by providing an integrated demonstration of the physics and technology required for a fusion power plant.

Rapid progress has been made in the design, manufacturing, construction and R&D activities, and, as shown in Fig. 26.2, the facility is now taking shape at St-Paul-lez-Durance in southern France.

Fusion Technology is going beyond what is currently known and looks for Materials having strong mechanical capacities at very high temperatures in Normal/Accidental Scenarios and beyond design Basis Scenarios. Electromagnetic Loads, Disruption Loads, impulsive burst explosion loads, seismic loads and Aircraft Crash loads have to be considered in design loads combinations when Plasma Temperatures is above 150 million of degrees Centigrade and severe confinement is required to assure Primary Barrier decoupled from Plasma functional Scenario. It is difficult, but challenging. The major objective of the ITER project is to demonstrate that a future power producing fusion device can be maintained effectively and offer practical levels of plant availability.

Fusion powers the Sun and stars: two hydrogen nuclei combine, form a heavier nucleus and release energy (Fig. 26.3). Our objective is to reproduce this reaction on Earth.

S. Orlandi (✉)
International Thermonuclear Experimental Reactor, Saint-Paul-lez-Durance, France
e-mail: sergio.orlandi@iter.org



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Fig. 26.1 ITER—International agreement among seven members

Fig. 26.2 Aerial view of the ITER site at St-Paul-lez-Durance with the construction of the Assembly Hall and Tokamak Complex

The process of nuclear fusion is summarized in the following steps:

- Heat Deuterium-Tritium plasma to 150 million °C.
- Confine and shape the plasma with magnetic fields.
- Sustain a "burning plasma" with helium nuclei.

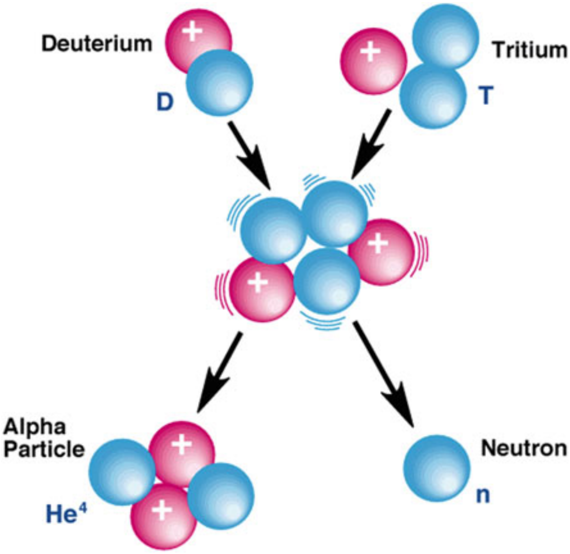



**Fig. 26.3** Fusion reaction deuterium tritium

- Transfer neutron energy to the metal walls.
- Heat water → Steam → Electricity.

Nuclear Fusion Energy production advantages are listed:

- Massive, continuous, baseload energy;
- Safe, no meltdown possible;
- No $CO_2$ or other greenhouse gases;
- No long-lived high-activity radioactive waste;
- Unlimited fuel for millions of years.

ITER Mission (Fig. 26.4) is concentrated in getting demonstration to be able to produce industrial-scale fusion producing a “burning plasma” having:

- $Q \geq 10$—Gaining Factor;
- 50 MW of heating input—Required energy to work;
- 500 MW of thermal output—Energy produced.

The mechanism to assure nuclear fusion into the chamber (called Vacuum Vessel) is achieved running an electrical current in the DT gas in order to create a *plasma status*, heating with electromagnetic waves and inject high-energy neutrons.

The result: is to reach the temperature for fusion equal to 150,000,000 °C.

A giant magnetic cage is going to be built assembling together the central solenoid (13 m high and 1000 t), eighteen toroidal magnets (17 m high and 360 t each one) and six poloidal magnets (8 up to 24 m of diameter, 200 up to 400 t each one) Figs. 26.5 and 26.6.

The current situation in installation progress is summarized in the picture (Fig. 26.7).

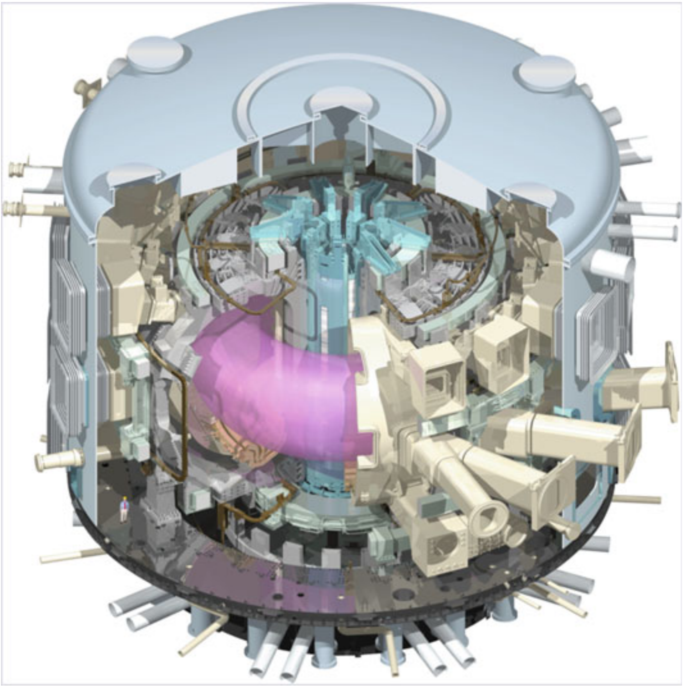


**Fig. 26.4** ITER machine global assembly

**Fig. 26.5** Poloidal field coils

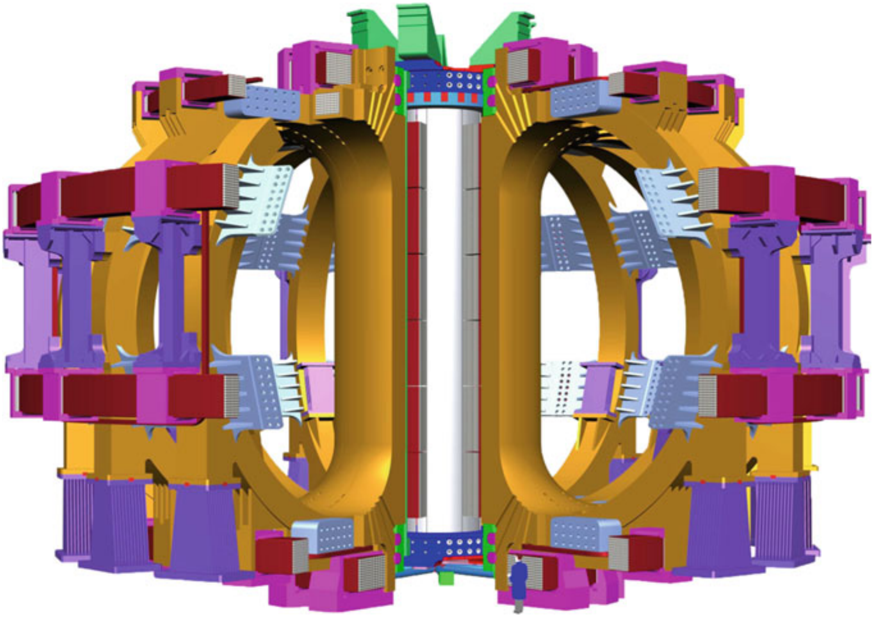


**Fig. 26.6** Integration PF/TF coils and VV-cage

**Fig. 26.7** ITER plant overview

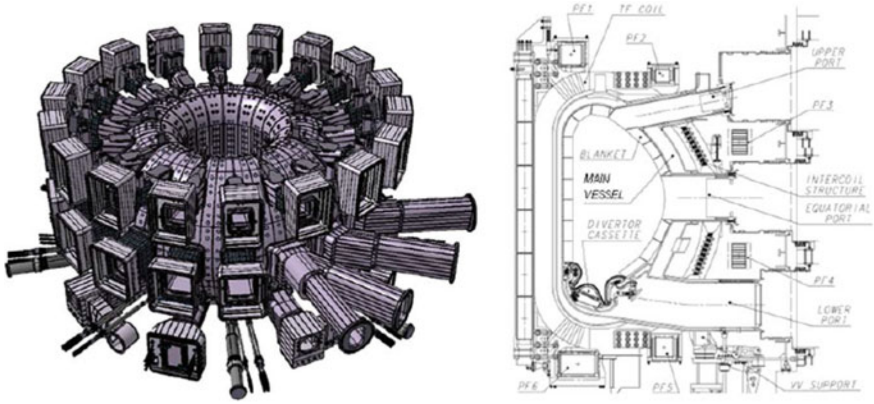
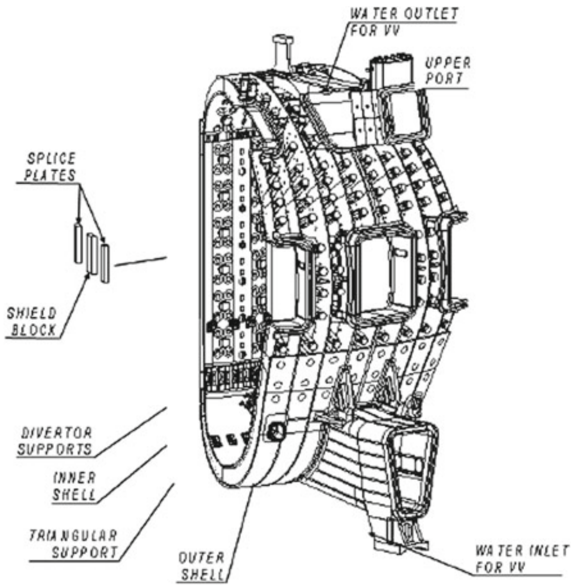



**Fig. 26.8** General overview of the Vacuum Vessel and Tokamak poloidal overview

**Fig. 26.9** Vacuum Vessel overall arrangement




*Systems Description*—Vacuum Vessel: The main component of ITER, where the fusion reaction takes place, is the Vacuum Vessel (VV), composed by the main vessel, the port structures and the VV supporting system (Fig. 26.8).

The Vacuum Vessel is a torus-shaped double wall structure with shielding and cooling water between the shells (Fig. 26.9). The basic vessel design is an all-welded structure where the inner shell serves as the first confinement barrier for the in-vessel radioactive inventory. The Vacuum Vessel is divided into nine toroidal sectors joined by field welding using splice plates at the central vertical plane of alternate ports (of the odd numbers). The sectors are connected to each other with the splice plates with the provision for twofold cutting and re-welding.

At the upper level, there are 18 ports of a similar design. At the equatorial level, there are 14 regular equatorial ports and three ports for the neutral beam injection (NB ports). At the lower level, there are five ports for divertor cassette replacement and/or diagnostics (the divertor Remote Handling/diagnostic ports), and four ports for vacuum pumping (the cryopump ports). Between these ports, there are local penetrations for ELM coil penetrations, divertor piping, in-vessel viewing and glow discharge cleaning of the in-vessel components. The port structure is attached to the port stub (integral to the main vessel) and includes the port stub extension, and the port extension (normally equipped with the connected duct extended to the cryostat). The port components are connected to each other with the splice plates.

The main characteristics of the Vacuum Vessel are summarized in Table 26.1.

Water Cold Sinks: The Cooling Water system is designed to remove the high heat deposition on the Vacuum Vessel either during normal operation (the total heat deposition is non-uniformly deposited and mainly due to nuclear heating) or during off-normal operation (the decay heat of the VV and thermal radiation from the in-vessel components such as blanket and divertor—Fig. 26.10).

The ITER Cooling Water System is composed of four main systems (Fig. 26.11):

- the Tokamak Cooling Water System (TCWS);
- the Component Cooling Water System (CCWS);
- the Chilled Water System (CHWS);
- the Heat Rejection System (HRS).

The TCWS removes heat from the Vacuum Vessel (through the Vacuum Vessel Primary Heat Transfer System, VV-PHTS), from the in-Vacuum Vessel Components (through the Integrated loop of Blanket, Edge Localized Mode-Vertical Stabilization Coils, and Divertor PHTS, IBED-PHTS) and the Neutral Beam Injectors (through the NBI-PHTS).

The Tokamak Cooling Water System also employs some supporting systems such as the Draining and Refilling System (DRS), the Drying System (DYS) and the Chemical and Volume Control System (CVCS).

The Component Cooling Water System is an intermediate closed loop that transfers heat to the Heat Rejection System (HRS) for final disposal to the atmosphere. CCWS-1 also provides cooling for some other nuclear systems (e.g. Tritium Plant Systems components, etc.).

The non-nuclear systems (power supply, busbars, cryoplant, chillers etc.) are cooled by four independent trains CCWS-2A, 2B, 2C, 2D (based on pressure, temperature and water chemistry demanded by the systems) which again transfers heat to the HRS.

Two Chilled Water Systems (CHWSs) are also present: CHWS-H1 provides cooling for Protection Important Components (PICs) via direct air heat transfer, whilst CHWS-H2 provides cooling for non-PICs.

**Table 26.1** Vacuum Vessel main parameters

| | |
|---|---|
| *Size* | |
| • Toroidal extent of sector | 40° |
| • Toroidal outside diameter | 19.4 m |
| • Torus inner diameter | 6.5 m |
| • Torus height | 11.3 m |
| • Shell thickness | 60 mm |
| • Rib thickness | 40, 60 and 80 mm in some locations |
| Structure | Double wall |
| *Configuration* | |
| • Inboard straight region | Cylindrical |
| • Inboard top/bottom | Double curvature |
| • Outboard region | Mainly double curvature |
| *Resistance* | |
| • Toroidal | 7.9 μΩ |
| • Poloidal | 4.1 μΩ |
| Water inlet temperature at normal operation during baking | 100 °C |
| | 200 °C for VV |
| | 240 °C for blanket water cooled ports |
| Water inlet absolute nominal pressure for main vessel at normal operation during baking | 0.8 MPa |
| | 2.1 MPa |
| Absolute pressure inside plasmach amber and cryostat chamber during normal operating conditions | 0 MPa (vacuum) |
| • Volume of coolant in main vessel (including the port stub extensions) | 200 $m^3$ (in all 9 sectors) |
| • Volume of coolant in the port extensions (cooled by the VV PHTS) | 35 $m^3$ |
| • Volume of coolant in port extension parts cooled by the FW/B1PHTS | ~0.142 $m^3$ per upper port<br>~0.045 $m^3$ per equatorial port |
| Design pressure (absolute values) | 2.6 MPa for main vessel + extensions |
| | 5.0 MPa for ports extensions cooled by First Wall and Blanket cooling system |
| Coolant | Water |
| Design temperature | 200 °C for VV |
| | 250 °C for ports |
| *Surface area/volume* | |
| • Interior surface area | ~850 $m^2$ |
| • Interior volume | |
| • Excluding volume of in-vessel components | ~1090 $m^3$ |

(continued)

**Table 26.1** (continued)

| | |
|---|---|
| • Including volume of in-vessel components | ~1600 $m^3$ |
| *Mass of the assembled vessel (360°)* | |
| • Main vessel (without shielding) | 1611 t |
| • Shielding | 1733 t |
| • Port structures (excl. connecting ducts) | 1487 t |
| • Connecting ducts | 294 t |
| Total | 5125 t |
| Allowable leak rate – Helium vacuum leak test | $1 \times 10^{-7}$ Pa $m^3$ $V^{-1}$ (air equivalent) |

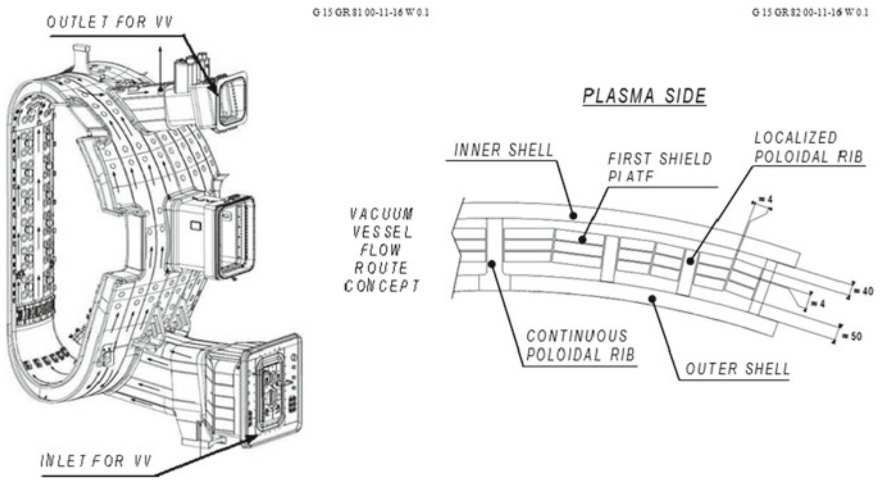
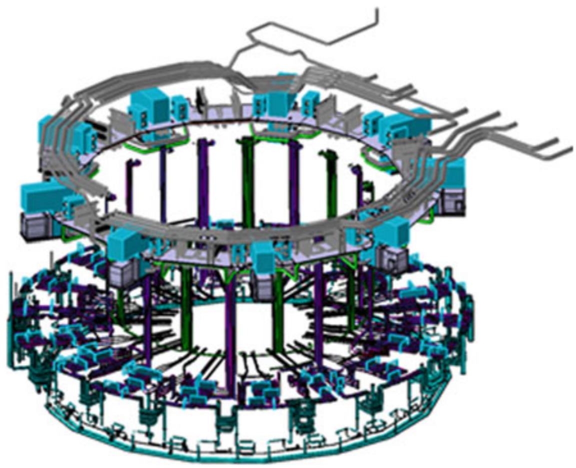



**Fig. 26.10** Vacuum Vessel water routing and water flow passage

**Fig. 26.11** Tokamak Cooling Water System (TCWS)



The Tokamak Cooling Water System, directly connected with Vacuum Vessel, has the following main functions:

- remove heat deposited in the in-vessel components (FW/BLK and DIV PHTS components) and the VV and NBI PHTS components during a plasma pulse and rejects this heat to CCWS-1;
- control the coolant temperature, flow rate and pressure for the in-vessel components VV and NBI during normal operation as required;
- control differential temperature between in-vessel components and the VV during all modes of operation;
- provide SIC signals to initiate drainage of the VV to the safety drain tanks during postulated Loss of Coolant Accident (LOCA) or Loss of Flow Accident (LOFA) events;
- remove decay heat during normal operation from the in-vessel components and the VV after plasma shutdown;
- provide decay heat removal by the VV PHTS after postulated loss of offsite power (LOOP) events;
- provide the primary confinement boundary of the radioactive inventory of the TCWS PHTS coolant for postulated failures of in-vessel components;
- measure the heat removed from the in-vessel components and VV to contribute to the determination of the overall fusion power balance.

The ITER vacuum vessel operates in normal operating condition at p ~ 0 MPa (vacuum) and in any case the maximum internal pressure shall be limited to 0.15 MPa absolute, in case of loss of coolant accident from the in-vessel components (coolant coming from the TCWS) or LOVA (loss of vacuum accident) event. In order to fulfil this Project Requirements the Vacuum Vessel has been equipped with an additional sub-system: the Vacuum Vessel Pressure Suppression System (VVPSS directly connected to VV).

In Fig. 26.12 plant layouts view of the Vacuum Vessel and the VVPSS.

The sub-system includes four Vapor Suppression Tanks (VST), one Small LOCA Tank and three Large LOCA Tanks, containing enough water at room temperature to condense the steam resulting from the Design Basis coolant leaks into the Vacuum Vessel, thus limiting over-pressurization to 0.15 MPa absolute. The system can also be utilized in a variety of other situations, such as a simple loss of vacuum, to provide over pressure protection and enhanced confinement by maintaining low pressure in the system.

Four types of events are considered in the design of the VVPSS:

- Type 1 event: Pure LOVA;
- Type 2 event: Small Pure LOCA;
- Type 3 event: Large Pure LOCA;
- Type 4 event: Combination of LOVA and LOCA.

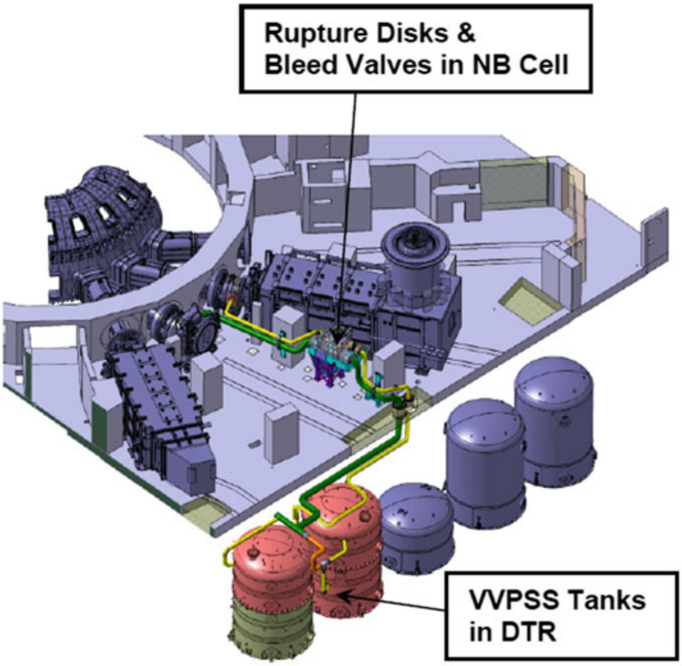



**Fig. 26.12** Plant layout view of the VV and VVPSS

Event type 2, 3 and 4 are considered as Beyond Design Basis Accident (BDBA) when the amount of steam generated exceeds the condensation capacity of the Vapor Suppression Tanks (in case of failure of the isolation valves on TCWS).

Cryogenic Cold Sink: While the cold sink for VV is the TCWS, the cold sink for Magnets assuring the confinement function of plasma is the cryogenic system. The purpose of the ITER cryogenic system is to provide the required operational conditions for the magnet system, vacuum system and small users like diagnostics. The magnet system consists of superconducting magnets coils, structure and current leads, and is supported by 80 K thermal shields system. The vacuum system consists of cryo-pumps for torus and cryostat, cryo-pumps for Neutral Beam Injection (NBI) and Pellet Injection System (PIS). The users of the cryogenic system require helium cryogen at temperature levels of 4.5, 50 and 80 K and nitrogen at either 80 K or ambient temperature. The cryogenic system needs to satisfy all operational modes of the users at various stages of plasma operation. To satisfy the operational modes and resulting requirements, the ITER cryogenic system has been divided according to the ITER Geographical Breakdown System (GBS) in two different locations namely the cryoplant System (in cryoplant buildings and cryo-bridge) and the cryo-distribution system (in the Tokamak).

The ITER cryogenic system, see Fig. 26.13, has to guarantee stable operation conditions for the magnets and cryosorption panels over a wide range of plasma

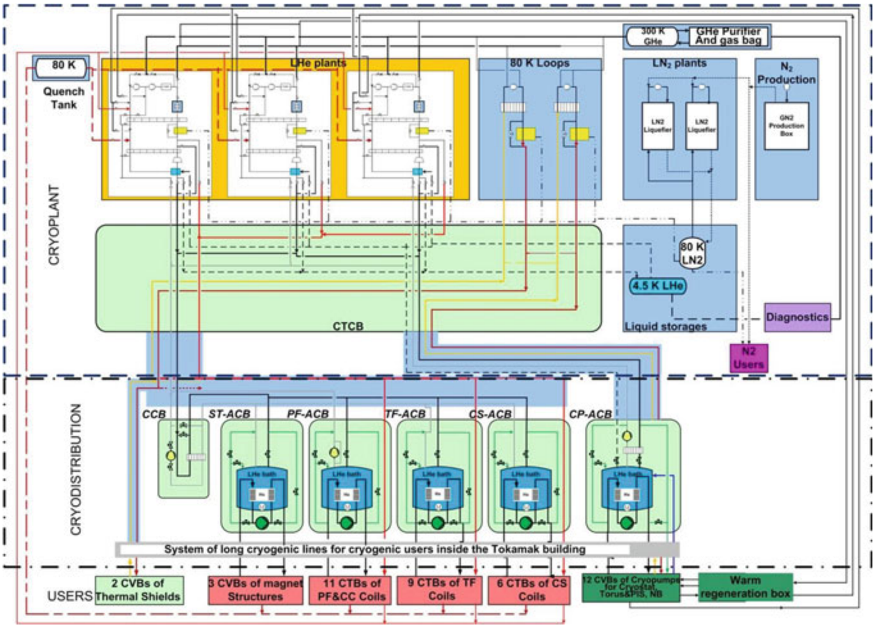



Fig. 26.13 Cryogenic system global architecture

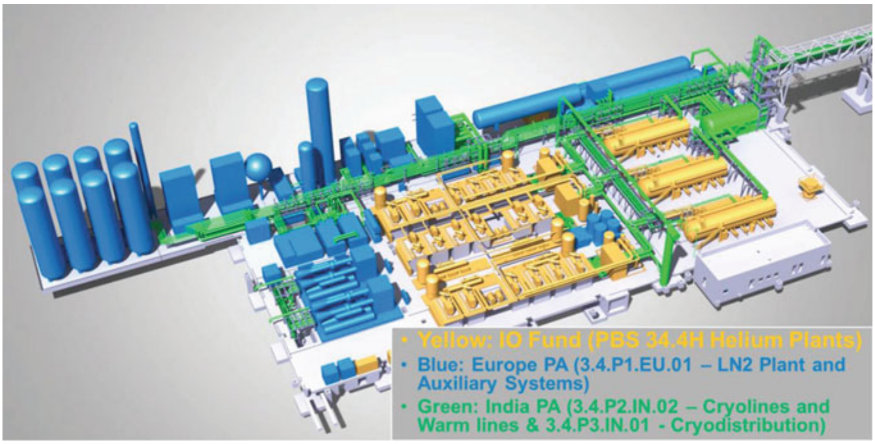



Fig. 26.14 Cryoplant system 3D layout

scenarios ranging from short (~100 s) plasma pulses with enlarged fusion power (700 MW) to long plasma burn times (3000 s) at reduced fusion power of 365 MW, whereas the baseline is 500 MW for 400 s.

As one of the world's largest cryogenic infrastructure, see Figs. 26.14 and 26.15, the ITER cryoplant will provide an average cooling power of 75 kW at 4.5 K during

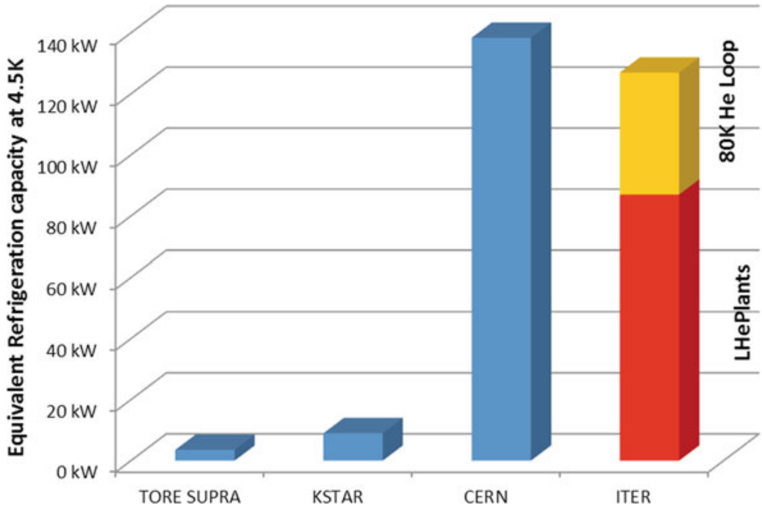



**Fig. 26.15** Comparison of ITER cryo-plant helium cooling capacities

plasma experiments and up to 87 kW in pure refrigeration mode through three LHe plants. For the thermal shield of the Tokamak and cryo-distribution, two 80 K helium loops with an average capacity of 40 kW equivalents at 4.5 K (2 × 4 kg/s loops in between 80 and 100 K) will be installed.

Two liquid nitrogen ($LN_2$) refrigerators with a maximum capacity of 1300 kW at 80 K will support the nitrogen pre-cooling system of all helium plants. ITER will have its own nitrogen production facility on site, provided by a nitrogen generator of ~1550 N $m^3$/h capacity for blanketing, leaks, purifier, regeneration of dryers as well as a redundancy in case of instrument air network failure.

An impurity processing system recovers and purifies helium from safety valves and other open circuit users. A heat recovery system (HRS) will recover up to 12 MW of heat from the cooling water circuits of the screw compressors for heating of the ITER buildings.

Storage and recovery of the helium inventory is managed via warm and cold (80 and 4.5 K) helium tanks.

ITER will have to store an overall helium inventory of 27 t. The storage system has been optimized and its cost reduced with the replacement of part of the warm storage vessels with a 175 $m^3$ LHe dewar. The storages, including those for large volumes of gaseous and liquid nitrogen, are summarized in Table 26.2 and its layout in Fig. 26.16.

For the first time a large and distributed cryogenic system has to consider the constraint of a nuclear installation while aiming at maximizing the efficiency, flexibility, availability and reliability of operation required to demonstrate the economic viability of fusion for future energy production. As a nuclear installation, the ITER

**Table 26.2** Storage inventory and capacity

| | Volume (mc) | Total volume (mc) |
|---|---|---|
| Pure gas helium tanks at ambient temperature | 5 × 400 | 2000 |
| Impure gas helium storage at ambient temperature | 1 × 400 | 400 |
| LHe tank | 1 × 175 | 175 |
| Helium quench tanks | 2 × 360 | 720 |
| Helium gasbag | 7 × 120 | 840 |
| $LN_2$ storage | 1 × 300 | 300 |
| Gas nitrogen storage | 1 × 100 | 100 |

**Fig. 26.16** Cryogenic system installed in buildings 51/52

project is under the French Quality Order 1984 (French decree relating to the quality of design, construction and operation) which has been rolled-out to contractors and sub-contractors. Codes (mainly for pressure vessels) are imposed and strictly followed unless proper counter measure could be implemented. One of the main issue for IO as a nuclear operator is maintenance of all vacuum insulated pressure vessels which forces the design to take all measure to assure or avoid such activities of periodic inspections and requalifications.

A Reliability Availability Maintainability Inspectability (RAMI) analysis is developed and detailed along all design phases, with contractors and re-integrated to IO overall RAMI analysis.

For protection of investment as well as personal, Hazard and Operability (HAZOP) and Safety Integrity Level (SIL) studies are systematically conducted.

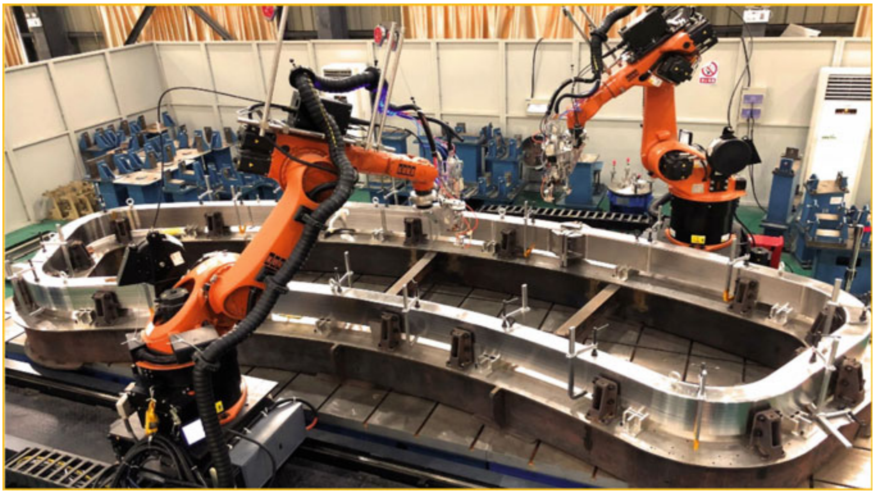


**Fig. 26.17** Engineering innovation—robotics

In order to meet RAMI, HAZOP and SIL requirements, the cryoplant technical specification refers to the European or International standard such as EN ISO 10440-1 for rotary-type positive-displacement compressor or EN ISO 10438 for lubrication, shaft-sealing and control-oil systems and auxiliaries. All rotating machineries have to follow either an ISO standard or its equivalent from the American Petroleum Institute (API). The heat exchanger will follow the TEMA (Tubular Exchanger Manufacturer Association) or ALPEMA (Aluminium Plate Fin Exchanger Manufacturer Association) standards.

Maintenance and In Service Inspection (ISI)—The World of Remote handling system and Robotics: A major objective of the ITER project is to demonstrate that a future power producing fusion device can be maintained effectively and offer practical levels of plant availability. During its operational lifetime, many systems of the ITER machine will require maintenance and modification; this can be achieved using remote handling methods. The need for timely, safe and effective remote operations on a machine as complex as ITER and within one of the world's most hostile remote handling environments represents a major challenge at every level of the ITER Project organization, engineering and technology. Remote handling (RH) is the synergistic combination of technology and engineering management systems (Fig. 26.17) to enable operators to safely, reliably and repeatedly perform manipulation of items without being in personal contact with those items. ITER mission requires scheduled upgrades of the machine, by means of exchanging internal components, executing scheduled and unscheduled maintenance and/or repair operations.

To accomplish such tasks, ITER has adopted a RH maintenance plan (IRHMP). This is based on the maintenance system (IMS) equipment, on the IMS facilities (hot cell, test stand) and on a set of operational procedures. The RH approach required

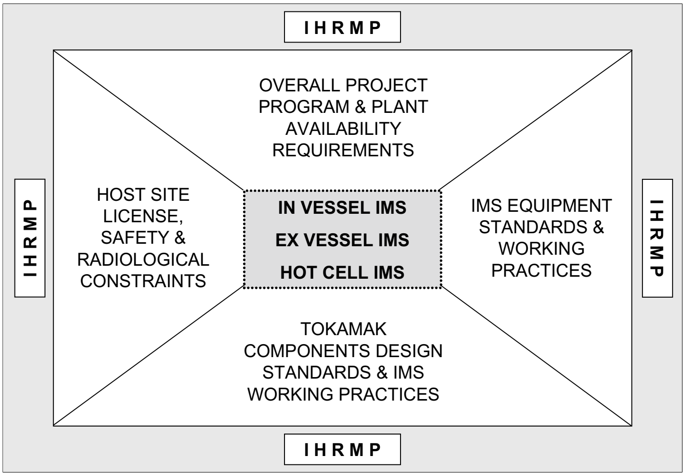



**Fig. 26.18** Logic of the ITER IRHMP and its relation with the IMS

for a fusion device like ITER is characterized by: (a) geometrically complex working environment, (b) large, heavy components with close tolerance fits, (c) limited access through narrow ports; (d) poor visibility, (e) the RH equipment comprises combination of large transporters, specialised end-effectors (including teleoperated manipulators) and tooling, (f) relatively long distance between reactor and hot cell, (g) hot cell dimensions and functions. To complicate matters further, the environmental conditions in which the RH equipment is required to operate are: (a) ultra high vacuum clean conditions, (b) high gamma radiation, (c) contamination, e.g. beryllium dust, tritiated carbon dust, gaseous tritium and activated tungsten dust, (d) some level of magnetic field. The ITER Remote Handling Management Plan (IRHMP) (being developed, Fig. 26.18) will be the reference for the management of the specification, design, procurement and operation of all the ITER remote handling equipment and facilities, including the RH compatibility of ITER components.

The objectives of the IRHMP are to: (a) establish and manage the ITER requirements for in-vessel components maintenance and upgrade, on the basis of the IMS equipment and facilities availability, (b) define the IMS performance parameters and operational limits, (c) define the IMS deployment strategy for planned and unplanned maintenance based on the IMS operational & safety limits and on the established machine experimental program, (d) develop an IMS information package, to allow good planning of in-vessel components' maintenance & upgrade campaigns, (e) define and facilitate the use of best practice and standards for the specification, design and manufacture of the IMS, (f) define the best practice and standards for the design, manufacture and qualification of RH compatible ITER components, (g) define the best practice and standards to be used for the preparation and implementation of RH operations, (h) define and control the RH classification of ITER components.

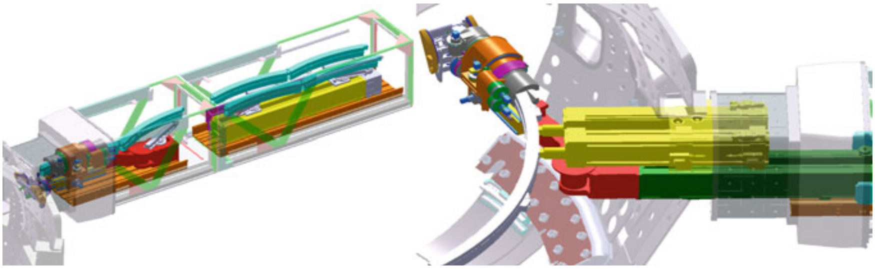


**Fig. 26.19** Blanket RH 3D simulation

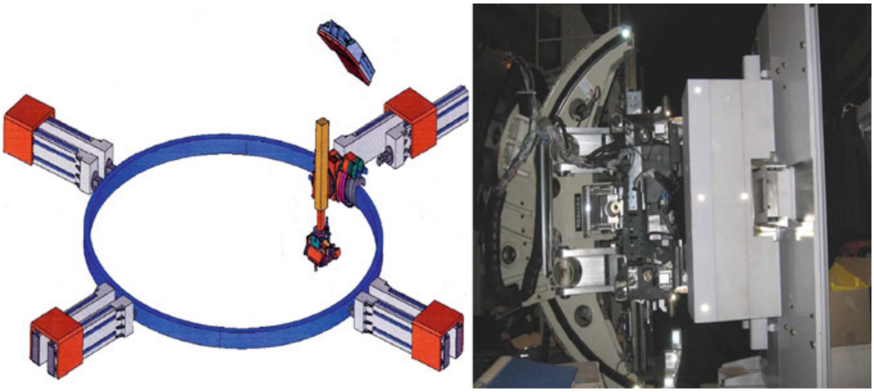


**Fig. 26.20** Blanket RH trials using the IVT and manipulator

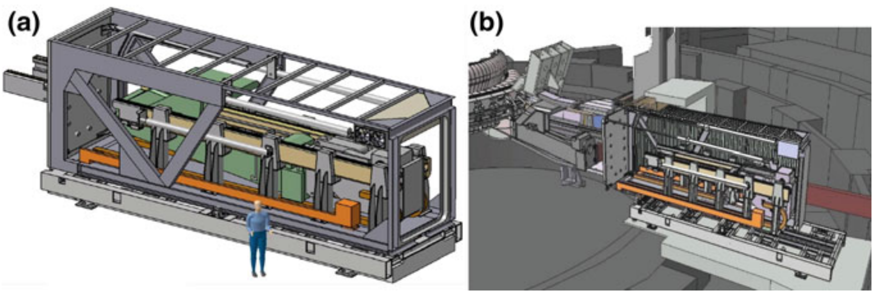



**Fig. 26.21** The equatorial transfer cask (**a**) and the divertor transfer cask (**b**)

The blanket RH equipment design has progressed in the JA-DA to include the CATIA modeling of the blanket In Vessel Transporter (IVT) system and its deployment process simulation (Figs. 26.19, 26.20 and 26.21). The process requires using dedicated, multiple pairs of IVT transfer casks (main IVT cask and intermediate IVT

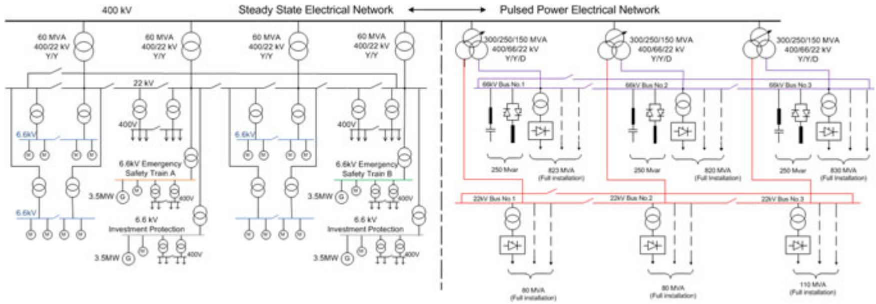



**Fig. 26.22** Electrical power distribution

cask) required for the support of the IVT rail, for the deployment of the IVT vehicle/manipulator system, for the system support services and for the blanket modules exchange system. Some key technology aspects have also been or will be validated through a dedicated R&D program (manipulator gears lubrication, IVT rail hinge mechanism, cable handling, etc.), as well as the development of a simulator for the positioning control of the IVT vehicle and gripper.

Electrical Networks and electrical conversion: The network that will control the power supply to the ITER plant basically consists of two parts: a network for steady state and a network for pulsed operations (Fig. 26.22). The steady state electrical network (SSEN) supplies the power needed to operate the plant including offices and the operational facilities. The major consumers are the cooling water and cryogenic systems requiring together about 80% of the total demand of 120 MW. The power is taken from the 400 kV network that winds across Southern France past Cadarache. The ITER pulsed power electrical network (PPEN) is also connected to the powerful high-voltage grid, it provides the large pulsed power needed to supply the superconducting coils and the heating and current drive (H&CD) systems. The AC power is received from the 400 kV high-voltage grid and transformed to intermediate levels (66 and 22 kV) via 3 step-down transformers. The total peak active pulsed power demand will be limited to 500 MW. This includes power required to operate and control the Poloidal Field coils, the power needed for the positioning and the shape control of the plasma current, and including the vertical stabilization, and power to supply the H&CD systems.

A so called "reactive power compensation" system, one of the largest ever built so far, will make sure that the power taken off the grid does not exceed the level impose by the French grid operator.

The pulsed power supply is summarized in the attached scheme (Fig. 26.23).

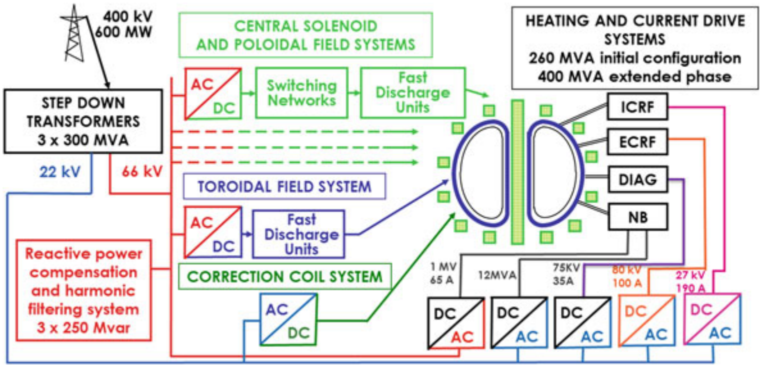



**Fig. 26.23** Pulsed Power Supply

The main function of the Central Solenoid and Poloidal Field AC/DC converters are the following:

- Power converters supply the magnets. However this is not the ultimate their main function. The main function is to control the plasma current and the plasma wall gaps.
- Using the Coil Power Supply Converters, the CS and PF coil currents are controlled and affect the configuration of the magnetic flux, which determines the plasma shape and position as well as the plasma current (Fig. 26.24).

The Coil Power Supply system is a large and intricate system that includes challenges, not only during the design and qualification, but also in the installation of the components into a very complex configuration:

- About 2 GVA installed power of high current (up to 68 kA), thyristor based, 4 quadrants, ac/dc power converters (most likely the world largest, high current conversion plant);
- 80 kA, 2.4 kV Switching Power Converters, which are quite beyond the industry practices;
- 750 Mvar, Static Var Compensator and Harmonic Filtering system, connected to 66 kV ac (the largest in Europe, most likely the 3rd largest in the world);
- 5 km bipolar busbars (max. cross-section: 420 × 270 mm);
- high reliable circuit breakers capable to carrying and interrupting up to 70 kA dc currents, and large resistors capable of discharging up to 50 GJ in about 30 s (first of its kind and key items for safety and investment protection).

ITER Vacuum System: The vacuum system will be one of the largest, most complex vacuum systems ever to be built. There are a number of large volume systems including: the cryostat (~8500 m$^3$), the torus (~1330 m$^3$), the neutral beam injectors (~180 m$^3$ each) and a number of lower volume systems including: the service vacuum system, diagnostic systems, and electron cyclotron transmission lines. In total there are more than 400 vacuum pumps of 10 different technologies required to pump

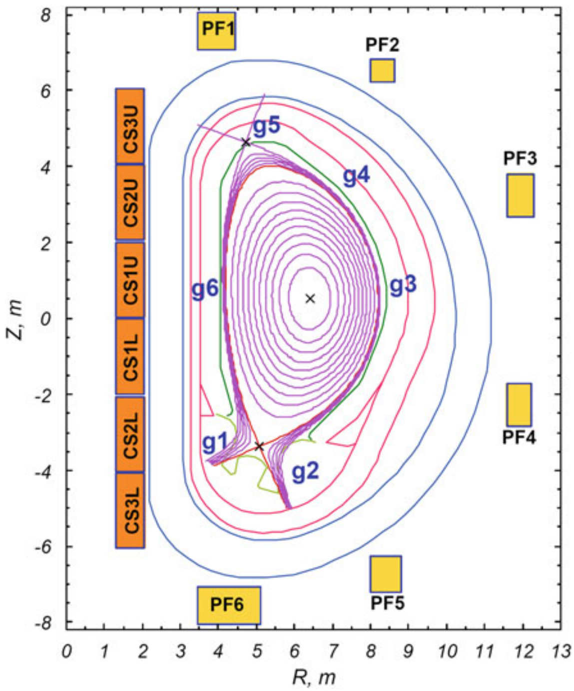



**Fig. 26.24** Plasma shape and position

the systems. The most demanding vacuum pumping applications are served by 18 large cryogenic pumps of 3 distinct custom designs. All of the vacuum systems are progressing from design, validation and into manufacturing (Fig. 26.25).

The ITER vacuum vessel and cryostat are to be directly pumped by a total of 8 cylindrical cryo-sorption pumps (Fig. 26.26) with integral 800 mm all metal vacuum valves.

The "build-to-print" design of these pumps is complete and the first pump is well advanced in manufacturing. All component parts have been manufactured, qualified and are now being assembled with completion expected in 2017. The 8 t flange of this cryopump, known as the "pump plug", is seen in Fig. 26.27.

The ITER neutral beam systems are each to be pumped by a pair of open structure panel style cryo-sorption pumps (Fig. 26.28) with a length of 8 m, and height of 2.8 m. They will achieve a pumping speed of 4500 $m^3/s$ for hydrogen. The final design of these pumps has involved development of new fabrication methods so as to significantly reduce the cost and manufacturing time for the thousands of cryo-panels and thermal shields within the pumps. The procurement process of the first pump, to the ITER "build-to-print" design, has commenced, this first pump is destined for the ITER neutral beam test facility (MITICA) in Padua.

*Conclusion*—ITER is a fantastic challenging adventure for scientists, engineering and physics. It is the dream of each of us to achieve the highest level of knowledge in technology and scientific applications. ITER is a fantastic opportunity to produce

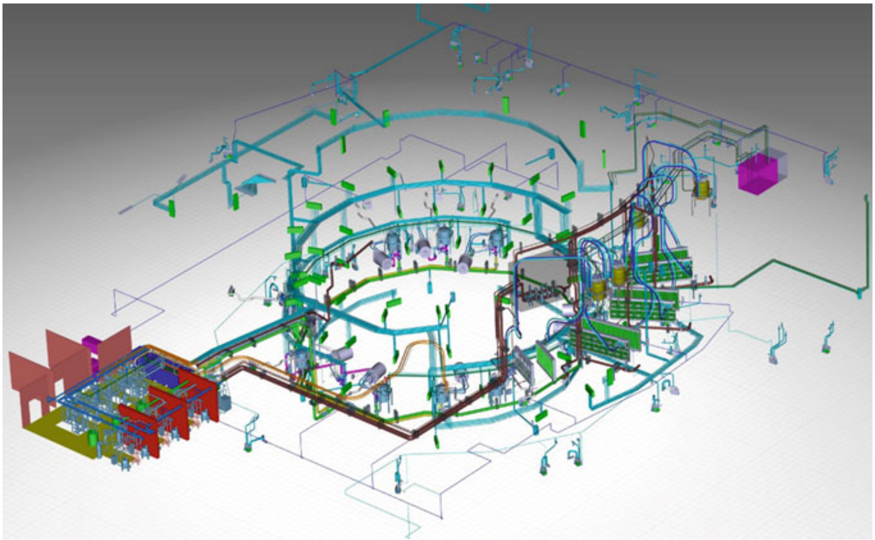


**Fig. 26.25** ITER vacuum system global view

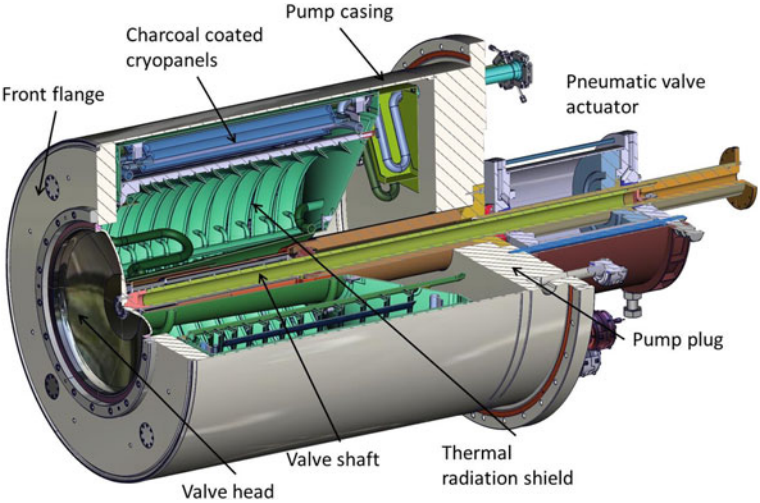



**Fig. 26.26** Torus and cryostat cryo-pump (1.8 m diameter)

transversal technologies to be applied in Medicine, aeronautics, aerospace, waste management, nuclear applications.

For all these reasons the Project belongs to all of us: we cannot fail in this fantastic effort.

**Fig. 26.27** Machined flange of the first Torus Cryo-pump

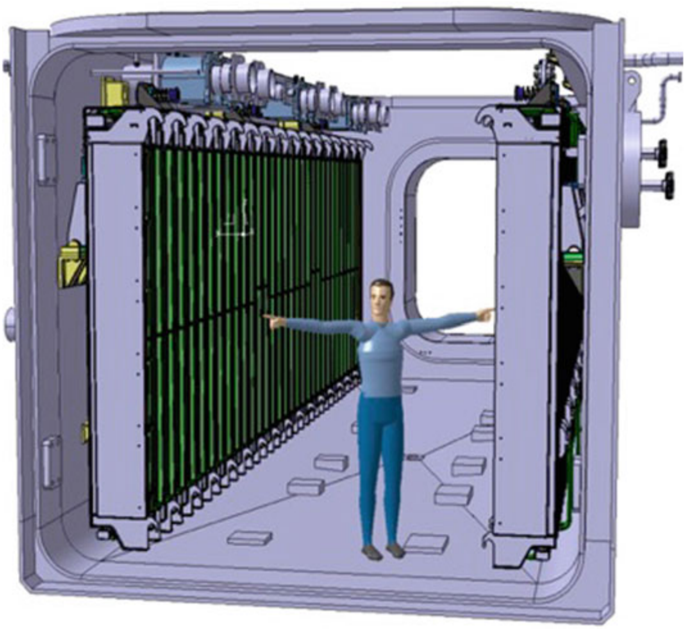


**Fig. 26.28** Nuetral injection cryo-pump

Let us work together to achieve with contributions generated all over the World the primary objective to get ITER Plant getting First Plasma within December 2025 and Nuclear Phase within 2035.

It is the way to get the Sun on Earth.
We are all sure: ITER is the way to a new, clean, safe and nearly unlimited energy.

# Chapter 27
# LIGO and Science Diplomacy

**Barry Barish**

The discovery of gravitational waves in LIGO captured the imagination of the public, worldwide. Why? The answer is one that is fundamental to the human race. A universal feature that sets humans apart from other living species is our curiosity about nature and the world we live in. Some of this knowledge is self-serving, like how to cope with diseases or how to improve our way of life. However, our curiosity goes well beyond just satisfying needs, as it includes our fascination with the stars, the origin of the universe, or just simply our understanding how things work.

Physics is one of the more obtuse areas of curiosity-driven science. It includes the study of the basic constituents that make up our physical world and how they interact. Yet, discoveries in this general area of science are considered front-page news! It is quite understandable that my colleagues from other areas of science often ask me about LIGO and gravitational waves, or the Higgs particle, or whether neutrinos move faster than the speed of light, etc. More interestingly, someone I meet often asks me the same questions on airplanes, at parties, or almost any gathering of people, when my identity as a physicist is revealed.

A key common interest of people all over the world are the science questions that physicists study. This universal interest, coupled with the international and non-political nature of the field, make physics research an ideal and unique tool for science diplomacy. Ironically, one of the most fundamental areas, particle physics, was born following World War II, out of the Atomic Bomb effort. The original research that led to the Atomic Bomb originated from the development of quantum mechanics and nuclear physics in the 1930s and the tools built in the bomb effort led to the peaceful worldwide physics research using particle accelerators after the war. Many of the same physicists, who were integral to the Atomic Bomb efforts, moved on to exploring fundamental questions in particle physics after the war, using ever-larger

B. Barish (✉)
California Institute of Technology, Riverside, CA, USA
e-mail: barish@caltech.edu



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particle accelerators, culminating in very large international facilities like those at CERN in Geneva, Switzerland.

A second area of fundamental physics is LIGO, an experimental facility to study Einstein's theory of general relativity, his prediction of the existence of gravitational waves and a new astronomical science with gravitational waves. These research topics are conducted by large international collaborations that grew up first with university facilities, but soon required larger collaborative facilities. Even though particle physics evolved from weapons laboratories after WWII, the field now has totally free access and requires no security clearances. Scientific results are published in scientific journals without censorship and with worldwide 'open-access.'

The public excitement with the science of gravitational waves and particle physics has created strong connections between the public and the science. This, along with the international nature of the fields, provides special opportunities for them to play special roles in relations between people from different countries.

*Science for Diplomacy*—The Royal Society in the UK and the American Association for the Advancement of Science in the U.S. have defined three types of science diplomacy: (1) "Science in diplomacy": Science can provide advice to inform and support foreign policy objectives; (2) "Diplomacy for science": Diplomacy can facilitate international scientific cooperation; and (3) "Science for diplomacy": Scientific cooperation can improve international relations. All three of these aspects of science diplomacy are important, but it is the third where fundamental physics has had and will continue to have the largest direct impact. Much of the research in fundamental physics is carried-out through international collaborations using large experimental facilities.

One of the best examples is the development of international collaborations to build and do science on large particle accelerators. As accelerators became larger and more international, the International Union of Pure and Applied Physics (IUPAP) took special interest in the international aspects of this field. As an organization, IUPAP, was formed in 1922 with the specific aim to "to stimulate and promote international cooperation in physics; to sponsor suitable international meetings and to assist organizing committees; to foster the preparation and the publication of abstracts of papers and tables of physical constants; to promote international agreements on other use of symbols, units, nomenclature and standards; to foster free circulation of scientists; to encourage research and education." IUPAP is presently composed of 59 member countries, representing their identified physics communities.

IUPAP has played a special role in internationalizing particle physics by establishing a standing committee, the International Committee on Future Accelerators (ICFA) to coordinate particle accelerator facilities on an international scale. In 1980, ICFA made a statement that has to a large extent been responsible for the almost total internationalization of the field. The statement, "ICFA Guidelines for the Interregional Utilization of Major Regional Experimental Facilities for High-Energy Particle Physics Research" contained two key guidelines that have operationally opened up the use of large particle accelerators to physicists from around the world, independent of politics or the wealth of the country. It passed a resolution that for the use of these expensive large accelerators:

- "The national or institutional affiliations of the teams should not influence the selection of an experiment nor the priority accorded to it,"
- "Operating laboratories should not require experimental groups to contribute to the running costs of the accelerators or colliding beam machines nor to the operating costs of their associated experimental areas."

These principles are being followed by every major accelerator laboratory, and this has resulted in creating an international model for participation in particle physics research that is truly open to scientists from around the world. Major accelerator laboratories in Europe, Asia, the US and Russia follow this model for participation. More and more, these large facilities have become the primary tools for addressing the forefront problems in the field, and the research is performed by international teams of scientists through partnerships between countries that provide the major resources and jointly share the governance of the research organizations.

*LIGO: A Model of Independent Worldwide Scientific Collaboration*—Albert Einstein gave us a new theory of gravity in 1915, more than 200 years after Newton introduced his Unified Gravity theory. Einstein's theory was the next big step in understanding gravity, especially as it applies to understanding our universe. As an outcome of this theory, Einstein predicted the existence of gravitational waves in 1916 and they were detected 100 years later in LIGO (Laser Interferometer Gravitational-wave Observatory). LIGO is a self-organized collaboration of scientists and scientific institutions from 18 countries and about a hundred institutions from around the world. LIGO is the natural extension of scientists collaborating across borders to accomplish joint scientific goals. LIGO has extended that model to a large collaboration having its own governance that is open to scientists from around the world.

The fact that such complex science done over decades is being accomplished without formal agreements between countries, funding agencies or the scientist's institutions bodes well for achieving complex goals jointly by nations, without the burdens of complex government agreements. The success opens the door for other cooperation between countries on complex problems with formal agreements being employed, only as required.

*CERN: A European Particle Physics Laboratory*—International scientific collaborations are also carried out through much more formal international treaties or other cooperative vehicles, like for the CERN Laboratory in Geneva Switzerland. The Large Hadron Collider (LHC) has become the centerpiece of the field of particle physics. Following World War II, Europe was no longer a world leader in physics research. Rebuilding European science represented a major challenge, but a group of physicists, including Edoardo Amaldi in Italy, Pierre Auger in France and Niels Bohr in Denmark had the idea of jointly creating a European laboratory for particle physics. They prophesized that such a laboratory would unite European scientists to share the costs of developing world-class future facilities.

CERN was established at an intergovernmental meeting of UNESCO in Paris in December 1951, where the first resolution concerning the establishment of a European Council for Nuclear Research was adopted. In 1953, the 12 founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia ratified the agreement, soon after the European Organization for Nuclear Research (CERN) was established and Geneva was chosen as the location. The laboratory was established as a treaty organization and this has given it stability over the vicissitudes of economies, politics, etc. over its 60 years.

At present, CERN having built the Large Hadron Collider (LHC), a ~10 billion dollar facility, is the most important particle physics laboratory in the world. It has made more than its share of major discoveries in particle physics, including the discovery of the Higgs boson, and more are likely to come. Following the guidance from ICFA, the experimental program at LHC is carried-out by international collaborations that extend far beyond the European countries who support and are member-states for CERN.

In addition to the direct science coming from CERN, it has had a major impact on technological developments that are being exploited around the world. Perhaps the invention that has had the broadest impact on our everyday life is the worldwide web invented by Tim Berners-Lee in 1990. He developed this distributed information system, in order to meet the demand for information sharing between scientists all over the world. In 1991, he had developed an early Web system with browsers, URLs, etc., and it was released to the particle physics community. Rather quickly, the Web was adopted throughout the academic world in universities and research laboratories. As systems developed to use the web on PCs, the usefulness spread from high tech laboratories having powerful computers to all of us, and it has quickly become an indispensable tool for everyday life.

Interestingly, the World Wide Web was developed in an international particle physics laboratory, where information is shared across national boundaries without restriction. Just as this policy has enable particle physics to advance as a worldwide joint enterprise, the associated resulting technologies are now available to be exploited openly without borders.

*The Next Particle Accelerator: A Global Initiative*—We have learned much about the benefits of international collaboration in science, such as those on large accelerators for particle physics. International collaboration has enabled us, both by combining resources and talents, to make scientific breakthroughs that may not have been possible, otherwise. Further, the same international partnerships produces technical innovations and breakthroughs that can benefit society more broadly, and ones that can be disseminated throughout the world with few political obstacles.

This effort to develop a next generation particle accelerator are broadening yet further the science for diplomacy benefits being realized at CERN and, more generally, in particle physics. There are many issues involved in bringing scientists together in such an undertaking, such as obtaining visas for all participating scientists, intellectual property rights agreements between participating laboratories, industry and countries, importing sensitive scientific equipment, etc. These are all ways in which particle physicists are solving problems that are integral to enabling countries to work together.

Particle Accelerators are expensive, so one might well conclude that it is an area of science only available to scientists from richer countries. As I mentioned above, the guidelines from ICFA have made even the largest and most expensive accelerators, like the LHC, available to scientists from all around the world. The two large experimental collaborations at the LHC have more than 10,000 collaborating scientists and engineers from over 100 countries, as well as from hundreds of universities and laboratories. The global design effort for the next particle accelerator has several thousand scientists from around the world collaborating on the formative ideas and design stage. In these collaborations, all these scientists have equal access to the data and participate in small international groups on the specialized technical or physics efforts on the experiments. For scientists from developing countries, particle physics collaborations provide an almost unique opportunity to work with the most advanced.

*SESAME: Science for Diplomacy in the Middle East*—In addition to physicists from the developing countries participating in particle physics research at the major accelerator facilities, as discussed above, there are also important initiatives in the developing countries. Perhaps the most ambitious is an International Centre being developed in Jordan is called SESAME (Synchrotron-Light for Experimental Science and Applications in the Middle East). SESAME is an accelerator facility built in the Middle East as first established by UNESCO. The facility is located near Amman, Jordan, on a site donated by the Jordanian government, who also has built a very large modern building to house the accelerator and laboratories. The primary goal of the laboratory is to create a state-of-the-art synchrotron light research facility.

A synchrotron light source is a special particle accelerator that accelerates electrons to high energy and then converted them into a photon or light beam. Synchrotron light facilities are broadly used around the world for a wide range of research topics, including condensed matter physics, material science, biology and medicine. They also have many practical applications, such as doing precision lithography.

However, the importance of this initiative goes well beyond the scientific goals and is truly an example of how science can be used for diplomacy that cannot be accomplished otherwise. SESAME is a major intergovernmental scientific facility, whose members are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey. Like for the creation of CERN, the SESAME accelerator facility requires more resources than are possible for the individual member science budgets, as well as requiring the combined skills and talents to develop such a facility.

The stated aims of SESAME are admirable. They are: (1) "Foster scientific and technological capacities and excellence in the Middle East and the Mediterranean region (and prevent or reverse the brain drain) by constructing an outstanding scientific device and enabling world-class research by scientists in a diverse range of fields including biology and medical sciences, materials science, physics and chemistry, and archaeology; and (2) "Build scientific links and foster better understanding and a culture of peace through scientific collaboration. As the language of science is universal, scientists can try to build a bridge of understanding and perhaps trust for the benefit of all."

SESAME is the first major collaborative research facility in the Middle East and it is being formed following the success and organization of CERN as a model.

SESAME is being built using the CERN model for regional collaboration and scientific success. In addition, being undertaken in a region with so many long-standing political issues, it is an inspiring model how to bridge these differences. The project continues to face challenges and uncertainties, but a lot of progress has been made both technically and politically, due to the efforts of the members, especially Jordan. The enthusiasm of the scientists involved and the widespread international support have been keys to convincing the member governments having enormous political differences to collaborate and jointly provide resources for SESAME. This is a model and an existence proof that governments in the Middle East can work together on joint problems.

*Science for Diplomacy: Long Term Benefits*—Physics has proven to be a field where major nations are effectively pooling resources to develop the most advanced and ambitious forefront scientific instruments in the form of large particle accelerators, LIGO and large astrophysics facilities. The broad and open participation in physics research has provided a very successful model of Science for Diplomacy. The next generation of facilities is being developed through a truly global model, where the ideas, concepts, design and implementation are being done through global collaboration. The concept is being extended to building similar collaborative structures for particle accelerator facilities in less developed countries.

The most important benefit of the collaborations and partnerships formed for carrying out particle physics is less tangible, but very real. The close collaboration of particle physicists from all over the world to carry out today's research is creating a generation of scientists, for whom, working together across borders to solve common problems is both natural and effective. Hopefully, these attitudes can spread to influence positively countries working together on common problems, whether they be climate change or nuclear disarmament.

# Part VIII
# Forum-2

# Chapter 28
# Introduction

**Luciano Maiani and Raymond Jeanloz**

As note in the introduction to the forum talk given by Ambassador Grossi, the forum speakers would address broad topics that crossed some of the topics of the day's presentations and discussions, and time was allowed for other participants to ask questions or remark upon the whole day.

The forum speaker for the second and final day of the conference was Antonio Missiroli, NATO's Assistant Secretary General for Emerging Security Challenges. NATO is a military organization that has nuclear forces. NATO sees nuclear weapons as a core component of its deterrence and defense capabilities, and is committed to arms control, disarmament and non-proliferation, like the nuclear weapon states within the alliance (see https://www.nato.int/cps/en/natohq/topics_50068.htm). The organizing committee is committed to addressing problems in the real world, engaging thought leaders, moral leaders, and leaders in international security.

Dr. Missiroli discussed the overall environment of international security and trends in thinking in Brussels concerning non-nuclear emerging threats and the instruments that might be useful in addressing them. Deterrence remains a key element of international security in addressing some threats, but there is no operational model of deterrence in others, such as attacks in the cyber domain. In his talk and in the discussion that followed, Missiroli talked about means of reducing risks other than treaties: If we cannot limit the weapons, perhaps we can limit the targets. There is crossover between the cyber and the nuclear. Participants noted that any system, even air-gapped systems, can be attacked, so it is critical to protect nuclear command and control systems. Cooperation among the nuclear weapon states was suggested to try

L. Maiani (✉)
Accademia Nazionale dei Lincei, Rome, Italy
e-mail: luciano.maiani@cern.ch

R. Jeanloz
United States National Academy of Sciences, Washington, DC, USA
e-mail: jeanloz@berkeley.edu



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to prevent use of cyber tools to, in one way or another, catalyse nuclear war. Major new efforts like that are often undertaken only in response to major incidents. It will be a test of our rationality and humanity to see if we can work together without the prompting of a major incident.

# Chapter 29
# Promoting International Security During Difficult Times for Arms Control

**Antonio Missiroli**

*Editor's Note: This is a transcript of Dr. Antonio Missiroli's talk. The views presented in this intervention/article are personal and do not necessarily reflect those of NATO.*

Good afternoon. I owe you many thanks for inviting me to speak here today, and notably to conclude your proceedings, which is a great honour—especially as I am old enough to have learned my first (and, sadly, only) physics at school from 'the' Amaldi, the handbook of physics by Edoardo Amaldi that every student in Italy used back then. Also, as an Italian, being hosted in this building is a special privilege.

But I also owe you three apologies. The first one is that I am not a physicist. I am by training a boring historian and a superficial political scientist. So, please bear with my incompetence throughout my speech. The second apology is that I am not going to talk about nuclear disarmament and related issues. I am sure that throughout your proceedings you have already discussed at length, and dissected in depth, the current state of play. Addressing it would be to some extent even a little awkward on the part of someone representing NATO here. As you know, in principle NATO is not in favour of unilateral disarmament or the Ban Treaty. Therefore I could only go as far as to read some sort of official statement on the demise of the INF Treaty that would not add much to what you already know about the issue—and I do not think that you invited me here to do this.

Instead, and this is my third apology, I will try to discuss with you what else keeps us awake at night in Brussels—which is not unrelated to what you have been discussing so far. And I am saying 'in Brussels' because Brussels is, as you know, a city that hosts a flurry of international organizations and decision-makers and diplomats, in particular NATO and the European Union. The EU and NATO were famously said to be based in the same city but on different planets; and now, of course, the orbits of the two organizations have got ever closer, they are almost intertwined. Thus, in order to avoid collision, what we have to do is to compare notes, cooperate

A. Missiroli (✉)
North Atlantic Threaty Organization, Brussels, Belgium
e-mail: missiroli.antonio@hq.nato.int



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with and talk to one another. So what I am trying to relay is a set of concerns that occupy us all over there. And it is about the evolving strategic and security landscape at large, characterized as it is by increasing strategic competition, at both state and non-state level, globally as well as regionally. It is also characterized, and I'm sure you have discussed that, by a general weakening of the multilateral world order that goes from trade arrangements to arms control agreements and that seems to be happening ever more often.

What I would like to focus on in particular is the impact of technology on all this. Technology, in principle, is both a boon and a bane and, right now, we probably are in between two industrial and technological revolutions. One is the ICT revolution, so to speak, that is arguably still underway while we are probably transitioning already towards the next step in that revolution, which will be characterized by artificial intelligence, 5G technology, quantum computing and all that. We have started to realize only recently that, after enjoying all the benefits of the past or ongoing industrial revolution(s), we are now also starting to feel the sting or realize the 'dark side' of all that. We are just beginning to acknowledge the risks and the threats that it has also generated. And nowhere is that realization more acute than among security experts.

Let me give you a few examples. Take terrorism, which is very much in the minds of people in this part of the world as well as across the Atlantic. With the onset of ISIS, the Islamic State, terrorist actions in the Euro-Atlantic space have increased, and terrorist groups now use technology in a very effective way. In particular they use cyber space for propaganda and recruitment, for fund-raising as well as for operational purposes (a few months ago, for instance, the *New York Times* reported on the way in which militias use Whatsapp to coordinate their actions in Tripoli). But they also use 'physical' tools like drones, unmanned vehicles. You may have read that a couple of weeks ago an oil refinery in Saudi Arabia was attacked by a 'swarm' of drones, apparently carried out by Houthi rebels supported by Iran. In early 2018 a Russian military base in Syria was also apparently the target of a swarm of drones. Maybe the Middle East is a favourable ground for this kind of operations because there are large ungoverned spaces and big infrastructure is concentrated in small spaces. But perhaps it is not unconceivable to see drones operating even in urban environments, in our cities. You may remember that, less than one year ago, Gatwick airport in the UK was basically brought to a halt for two days right before Christmas by two drones that nobody has yet identified. The potential for harming entire communities is indeed enormous, especially if terrorists groups can load drones (that are easily accessible, available and operable) with CBRN agents or even improvised explosive devices.

Or take what we call cyber-attacks. A cyberattack is cyber against cyber, basically. There has been a spectacular increase in cyberattacks in the past few years, especially in 2017, when two major malware campaigns (WannaCry and NotPetya) affected critical infrastructure inside Europe and beyond, including hospitals in the UK and commercial shipping across the world. Malicious cyber activities occur on a daily basis, even routine incidents could easily escalate and be used to damage critical infrastructure: energy (including nuclear energy plants), transport, communication and also finance. The recent Nuclear Posture Review by the United States also highlighted the fact that cyber means could be used to disrupt and disable command and control systems for nuclear warfare. As you know very well, the first every cyber-attack was Stuxnet, launched against Iran in 2010–2011. Disabling the other side is part of the game, but there is also a wider risk of disruption and loss of control we all have to be aware of. Less than one year ago, Russia's attempt to hack into the website of the Organization against the Proliferation of Chemical Weapons (OPCW) in The Hague was discovered and exposed. And, in that particular case, the international community called out Russia for what it was doing.

This is an area in which the spectrum of potential hostile actors is wide and huge: from the so-called 'hacktivists' to the proverbial 'kid in the basement', from criminal gangs to terrorist groups, up to state sponsored actors: we call these APT (Advanced Permanent Threat) and most of them are located in China, Russia, North Korea and Iran. In some of these countries ministries are also directly involved in coordinating and directing all this. Hackers can steal our credentials, they can steal our money, they can steal industrial secrets, but they can also steal critical military information and carry out all sorts of online espionage. They can also exfiltrate data and perform large scale sabotage—all of which, in turn, could also be(come) part of a phased operation leading to overt conflict.

Insofar as these operations are covert actions for an intelligence operation, they are not even against international law as we know it: international law does not address espionage as such although law enforcement, especially at domestic level, can of course help address this issue. These operations are comparatively low cost and low risk, high impact and high reward; they are easy to deny, because tracking back algorithms rarely brings certainty in terms of attribution; they are difficult to detect, too, and difficult to deter. It is almost impossible to aim at absolute deterrence in this particular field, simply because the offence is at a structural advantage. They have the advantage of space and time: they can attack anywhere anytime as the attack surface in the digital world is virtually infinite.

Finally, and this is probably more of interest to you, traditional arms control and non-proliferation mechanisms cannot really work in this domain. Firstly, the legal framework at international level is very weak, as there is no such thing as the International Atomic Energy Agency in Vienna or the OPCW in The Hague to regulate this particular field. Secondly, traditional mechanisms of inspection, verification and disposal are not really applicable, if anything because the 'weapons', so to speak, range from a laptop to a code: not only cannot they be conclusively detected or destroyed, they can also be easily recreated. And, thirdly, there is no state monopoly on the legitimate use of code (as opposed to the legitimate use of force) and the threat actors in this domain are often beyond state authority or control.

It is also worth recalling that the kind of effects and the damage that these 'weapons' can create are not as visible or painful as physical effects. Therefore, it is also more difficult for the international community to mobilize against them, because there is no resulting moral or visual horror comparable to that produced by nuclear weapons. There has been no single case so far in which a cyberattack has brought so much damage that the international community was prompted to act against the perpetrators.

Even confidence building measures—as those traditionally applied in the WMD domain—do not really work. The Organization for Security Cooperation in Europe in Vienna has tried to engage its members in a dialogue to this end but with modest results, in part because some of the actors who have capabilities in this domain feel they have an edge and do not want restrictions that may erode it.

Last but not least, there is what we now call hybrid. By nature and definition, a 'hybrid' is a combination of different types of elements or, in this case, actions: military and non-military, covert and overt. It is what Russia did in Georgia in 2008 or in Ukraine in 2014. Interestingly, however, the original use of the term 'hybrid' in the context of warfare dates back to the conflict between Hezbollah and Israel in Lebanon in 2006, when Hezbollah used a multiplicity of different means—from hi-tech to very primitive tools, from urban guerrilla to conventional techniques against Tsahal, the Israeli Defence Force. That also included what we call the 'weaponization' of social media—something that is now probably familiar to you as citizens, something we have seen happen over the past few years in our democracies, on both sides of the Atlantic. Basically, 'hybrid' techniques entail and encompass a mix of disinformation, destabilization, disruption, deception, subversion, coercion—along a spectrum that ranges from espionage to sabotage. And virtually all are, now, cyber-enabled.

We have seen all this already, of course, especially during the Cold War. But what is indeed different now is the use of modern technology, which makes it much faster and more effective. Technology acts as a multiplier and accelerator and, potentially, as a game changer (also) in this field. First of all, it is changing the balance of power(s) worldwide, notably between the 'haves' (which are not necessarily the usual suspects, or at least not only) and the 'have-nots'. But it is changing also the internal balance of power in our own societies. You are surely familiar with the notion of the 'digital divide': some people have access to these technologies while some are excluded or are even victims of these technologies. An additional risk is a represented by the fact that some of the 'haves' may not be guided by the same values and principles that we are, thus raising the concerns about their future use of such new and potentially disruptive technologies—at least as long as there is no international legal framework to constrain and restrain their behaviour.

The UN is doing a lot of work in this particular domain, especially in terms of soft law and codes of conduct. As you know, there is ongoing work in New York on the so-called lethal autonomous weapons systems, and a group of selected governmental experts is working (again) on cyber-related issues. The general state of international relations, however, appears hardly favourable for any major multilateral breakthrough, at least at this stage. Therefore, our expectations have to be modest. The emphasis is increasing on what we call 'responsible state behaviour': since it is impossible to entirely deter these kinds of operation, it is important to be able to identify what they should *not* aim at. In other words, since it is impossible to limit the 'weapons', it should be advisable to limit at least their 'targets'.

Yet the new technologies are not simply changing the balance of power(s)—they are also altering the balance of players, mainly because their peculiarity is that they are mostly privately generated, privately owned and privately operated. Cyberspace is the most relevant case in point. Most of the technologies we are talking about have been developed in and by the private sector. That was not the case with nuclear, chemical, biological or radiological weapons: they were state-generated and therefore largely controllable through interstate negotiations. The new ones are not being developed privately but the time required to hit markets is much shorter than in the past. Although most of these technologies are intrinsically dual-use, more often than not market considerations trump security considerations (that applies even to our mobile phones). Therefore, we are confronted with a scale of risks and vulnerabilities that certainly was unconceivable before. Take Google, Facebook, Amazon, Microsoft or Apple, but also Huawei, Alibaba or Tencent. These are the new superpowers—and nothing comparable to the so-called 'military-industrial complex' of decades past.

The next industrial or technological revolution is about 5G technology, artificial intelligence, machine learning and quantum computing. That is the next stage in the Great Transformation. As American futurologist, Roy Amara, famously coined a law whereby we tend to overestimate the short-term impact of new technologies and to underestimate their long-term impact, and we may indeed be confronted exactly with this phenomenon now. We tend to be extremely worried about what may happen 3, 4, 5 years from now with the introduction of IG technology, but we may not be sufficiently foresighted to see what may come in 20 years from now. Another one, Alvin Toffler, also said that the future always comes too fast, and in the wrong order. In other words, we do not know what may truly happen not only five but especially ten or twenty years from now—as much as we surely did not see coming a few years ago what is on now. But we have to be sufficiently lucid to try and seize the opportunities that the new technologies offer. In the field of human health it is quite evident that artificial intelligence, for instance, offers a range of unprecedented benefits, especially for an aging mankind. But there are other areas in which we tend, instead, to be much more concerned about their possible effects. You are certainly familiar with the discussions on 'killer robots', 'Terminators', 'Robocops' and so on and so forth—especially, as I said, since there are rising powers that are not constrained by the same rules of the game or moral principles that we have developed and would like to maintain and foster. Therefore, mitigating and managing the risks is the other side of the coin: seizing the opportunities and exploiting the potential benefits, yes, but also mitigating and managing the risks.

However, the name of the game is no longer just deterrence, which probably cannot have the same meaning as the type of strategic and absolute deterrence that we have seen at work since 1945. It is also resilience—and resilience supported by education. Explaining to people what can be done with the new technologies, but also what should not be done is essential. Even countering the manipulation of public opinion that is happening with the weaponization of social media requires a lot of education—as well as a healthy information landscape, that is not always a given.

As Western and democratic societies, we suffer some limitations in this field. Externally, we do not necessarily want to replicate or imitate the behaviour of those who want to do us harm, we do not want to do tit-for-tats—an approach that somehow constrains our response options. And internally, of course, we do not want to limit our own freedoms in order to combat disinformation or disruption: we do not want to limit free speech or restrain ownership of media or industrial assets. So our very nature of open societies—our declared strength—may come to represent, at the same time, a potential vulnerability and a structural weakness.

My last point is that any effective action in this field must be a coordinated one, a team effort: at national level (whole of government as well as whole of society), at transnational level (especially between like-minded countries), and at international level (between and across multilateral and regional organizations). As these hostile activities—terrorist, cyber and hybrid attacks—know no geographical borders and no jurisdictional boundaries, we have to be able to do exactly the same: build trust, cooperate and exchange information between and across nations, organizations, public and private actors.

# XXI Edoardo Amaldi Conference



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# PROGRAM

## MONDAY, 7 OCTOBER

09.45 - 09.50 — TRIBUTE TO H.E. AMB. YUKIYA AMANO
FORMER DIRECTOR-GENERAL OF THE INTERNATIONAL ATOMIC ENERGY AGENCY

**WOLFANGO PLASTINO** – SCIENTIFIC SECRETARY OF THE XXI EDOARDO AMALDI CONFERENCE, ITALY

09.50 - 10.30 — OPENING ADDRESSES

**GIORGIO PARISI** – PRESIDENT OF THE ACCADEMIA NAZIONALE DEI LINCEI, ITALY

**MARCIA MCNUTT** – PRESIDENT OF THE NATIONAL ACADEMY OF SCIENCES, UNITED STATES OF AMERICA

**ELISABETTA BELLONI** – SECRETARY-GENERAL OF THE MINISTRY OF FOREIGN AFFAIRS AND INTERNATIONAL COOPERATION, ITALY

**IZUMI NAKAMITSU** (BY VIDEO) – UNDER SECRETARY-GENERAL, UNITED NATIONS

**FEDERICA MOGHERINI** (BY VIDEO) – *HR*, *EUROPEAN COMMISSION*

**RAYMOND JEANLOZ** – CHAIR OF THE XXI EDOARDO AMALDI CONFERENCE, UNITED STATES OF AMERICA

**LUCIANO MAIANI** – CHAIR OF THE XXI EDOARDO AMALDI CONFERENCE, ITALY

### KEYNOTE SPEECHES

CHAIRS

**GIORGIO PARISI** – PRESIDENT OF THE ACCADEMIA NAZIONALE DEI LINCEI, ITALY

**MARCIA MCNUTT** – PRESIDENT OF THE NATIONAL ACADEMY OF SCIENCES,
UNITED STATES OF AMERICA

10.30 - 10.50 — PROMOTING SECURITY AND PROSPERITY: HOW THE NON-PROLIFERATION REGIME AND THE SCIENTIFIC COMMUNITY CAN ADDRESS THE DEMANDS OF A CHANGING WORLD

**MOHAMED ELBARADEI** – *DIRECTOR-GENERAL EMERITUS OF THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)*

10.50 - 11.10 — SCIENCE FOR PEACE

**FABIOLA GIANOTTI** – *DIRECTOR-GENERAL OF THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)*

11.10 - 11.30 — COFFEE BREAK

**THE XXI EDOARDO AMALDI CONFERENCE**
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|---|---|
| 11.30 - 13.00 | PANEL 1 |
| | **NEW AND EVOLVING VOICES IN ARMS CONTROL AND DISARMAMENT** |
| | CHAIR: **ALBERTO QUADRIO CURZIO** |
| | PRESIDENT EMERITUS OF THE ACCADEMIA NAZIONALE DEI LINCEI, ITALY |
| | MESSAGE TO THE PARTICIPANTS OF THE XXI EDOARDO AMALDI CONFERENCE<br>**PAUL RICHARD GALLAGHER** – *SECRETARIAT OF STATE, HOLY SEE* |
| 11.30 - 11.50 | THE RISKS OF NUCLEAR PROLIFERATION: ADDRESSING THE CHALLENGE<br>**SEBASTIANO CARDI** – *MAECI, ITALY* |
| 11.50 - 12.10 | PREFERRED COURSES OF ACTION FOR SECURITY AS NUCLEAR ARMS CONTROL CHANGES IN THE 2020S<br>**TIBOR TÓTH** – *EXECUTIVE SECRETARY EMERITUS CTBTO* |
| 12.10 - 12.30 | INTERESTS AND CHANGING NEEDS FROM ARMS CONTROL, DISARMAMENT, AND NON-PROLIFERATION FOR INTERNATIONAL SECURITY<br>**ROBIN GRIMES** – *RS AND MOD, UNITED KINGDOM* |
| 12.30 - 13.00 | QUESTIONS AND DISCUSSION |
| 13.00 - 14.15 | LUNCH BREAK |
| 14.15 - 15.45 | PANEL 2 |
| | **NUCLEAR WEAPONS, NON-PROLIFERATION, AND THE BROADER SECURITY ENVIRONMENT** |
| | CHAIR: **FRANCESCO CALOGERO** |
| | SAPIENZA UNIVERSITY OF ROME, ITALY |
| 14.15 - 14.35 | NUCLEAR WEAPONS, INTERNATIONAL SECURITY, AND NON-PROLIFERATION IN THE 2020S<br>**C. S. ELIOT KANG** – *STATE DEPARTMENT, UNITED STATES OF AMERICA* |
| 14.35 - 14.55 | RUSSIA'S VISION FOR ARMS CONTROL, DISARMAMENT, AND NON-PROLIFERATION<br>**VLADIMIR LEONTIEV** – *MFA, RUSSIAN FEDERATION* |
| 14.55 - 15.15 | PERSPECTIVES ON NUCLEAR SAFETY, SECURITY, SAFEGUARDS AND NON-PROLIFERATION<br>**LI HUA** – *CAEP, PEOPLE'S REPUBLIC OF CHINA* |
| 15.15 - 15.45 | QUESTIONS AND DISCUSSION |
| 15.45 - 16.00 | COFFEE BREAK |

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16.00 - 17.30 PANEL 3

**REALIZING THE PROMISE OF THE NON-PROLIFERATION REGIME THROUGH COOPERATION AND MONITORING**

CHAIR: **MARVIN ADAMS**

TEXAS A&M UNIVERSITY, UNITED STATES OF AMERICA

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| 16.00 - 16.20 | THE IAEA FOR BUILDING FUTURE SAFEGUARDS CAPABILITIES<br>**MASSIMO APARO** – *IAEA* |
| 16.20 - 16.40 | SCIENCE AND TECHNOLOGY FOR PUTTING AN END TO NUCLEAR EXPLOSIONS<br>**TAMMY TAYLOR** – *CTBTO* |
| 16.40 - 17.00 | CHALLENGES AND OPPORTUNITIES IN SCIENTIFIC AND TECHNOLOGICAL SUPPORT FOR MONITORING IN THE NON-PROLIFERATION REGIME<br>**JILL HRUBY** – *SNL, UNITED STATES OF AMERICA* |
| 17.00 - 17.30 | QUESTIONS AND DISCUSSION |

17.30 - 19.00 FORUM

**MAJOR CHALLENGES, OPPORTUNITIES, AND NEXT STEPS FOR THE PARTIES TO THE NUCLEAR NON-PROLIFERATION TREATY APPROACHING THE 2020 REVIEW CONFERENCE**

CHAIRS

**LUCIANO MAIANI** – ACCADEMIA NAZIONALE DEI LINCEI, ITALY
**RAYMOND JEANLOZ** – NATIONAL ACADEMY OF SCIENCES, UNITED STATES OF AMERICA

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| 17.30 – 18.00 | **RAFAEL GROSSI** – *MFA, ARGENTINE REPUBLIC*<br>*NPT REVCON* |
| 18.00 – 19.00 | GENERAL DISCUSSION |
| 20.00 | WELCOME RECEPTION AT THE ACCADEMIA NAZIONALE DEI LINCEI |

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## TUESDAY, 8 OCTOBER

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| 9.45 - 11.15 | PANEL 4<br>**PERSPECTIVES ON NUCLEAR NON-PROLIFERATION – PART I**<br>CHAIR: **CARLO SCHAERF**<br>PRESIDENT OF THE INTERNATIONAL SCHOOL ON DISARMAMENT AND RESEARCH ON CONFLICTS, ITALY |
| 9.45 - 10.05 | THE IRANIAN NATIONAL PERSPECTIVE ON NUCLEAR NON-PROLIFERATION<br>**KAZEM GHARIB ABADI** – *MFA, ISLAMIC REPUBLIC OF IRAN* |
| 10.05 - 10.25 | THE PAKISTANI NATIONAL PERSPECTIVE ON NUCLEAR NON-PROLIFERATION<br>**MUHAMMAD NAEEM** – *PAEC, ISLAMIC REPUBLIC OF PAKISTAN* |
| 10.25 - 10.45 | ADAPTING NON-PROLIFERATION APPROACHES TO A CHANGING WORLD: A EUROPEAN EXPERT'S VIEWPOINT<br>**CAROLINE JORANT** – *SDRI, FRANCE* |
| 10.45 - 11.15 | QUESTIONS AND DISCUSSION |
| 11.15 - 11.30 | COFFEE BREAK |
| 11.30 - 13.00 | PANEL 5<br>**PERSPECTIVES ON NUCLEAR NON-PROLIFERATION – PART II**<br>CHAIR: **STEVE FETTER**<br>UNIVERSITY OF MARYLAND, UNITED STATES OF AMERICA |
| 11.30 - 11.50 | THE ISRAELI PERSPECTIVE ON NUCLEAR SECURITY, NUCLEAR SAFETY AND NON-PROLIFERATION<br>**DAVID NUSBAUM** – *IAEC, ISRAEL* |
| 11.50 - 12.10 | OPTIONS FOR ADDRESSING THE DPRK NUCLEAR PROGRAM<br>**YOUNG-HO PARK** – *KPF, REPUBLIC OF KOREA* |
| 12.10 - 12.30 | REGIONAL RIVALRIES AND THEIR IMPLICATIONS FOR THE SECURITY AND NUCLEAR NON-PROLIFERATION REGIMES<br>**PAOLO COTTA-RAMUSINO** – *PUGWASH* |
| 12.30 - 13.00 | QUESTIONS AND DISCUSSION |
| 13.00 - 14.15 | LUNCH BREAK |

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14.15 - 15.45 PANEL 6

**INTERNATIONAL TECHNICAL COOPERATION AND THE ROLE OF SCIENCE DIPLOMACY**

CHAIR: **MICAH LOWENTHAL**

DIRECTOR OF CISAC - THE NATIONAL ACADEMY OF SCIENCES, UNITED STATES OF AMERICA

14.15 - 14.35 ENGAGING SCIENTISTS CITIZENS, AND INTERNATIONAL YOUTH IN DIPLOMACY TO ABOLISH NUCLEAR WEAPONS
**ALICIA SANDERS-ZAKRE** – *ICAN*

14.35 - 14.55 ITER PROJECT: INTERNATIONAL COOPERATION AND ENERGY INVESTMENT
**SERGIO ORLANDI** – *ITER*

14.55 - 15.15 LIGO AND SCIENCE DIPLOMACY
**BARRY BARISH** – *LIGO*

15.15 - 15.45 QUESTIONS AND DISCUSSION

15.45 - 16.00 COFFEE BREAK

16.00 - 17.30 FORUM

**PROMOTING INTERNATIONAL SECURITY DURING DIFFICULT TIMES FOR ARMS CONTROL**

CHAIRS

**LUCIANO MAIANI** – ACCADEMIA NAZIONALE DEI LINCEI, ITALY
**RAYMOND JEANLOZ** – NATIONAL ACADEMY OF SCIENCES, UNITED STATES OF AMERICA

16.00 - 16.30 **ANTONIO MISSIROLI** – NATO

16.30 - 17.30 GENERAL DISCUSSION

17.30 - 17.45 CLOSING OF THE CONFERENCE

18.00 - 20.00 GUIDED TOUR OF VILLA FARNESINA AND BIBLIOTECA CORSINIANA

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| **MARVIN ADAMS** | HTRI PROFESSOR OF NUCLEAR ENGINEERING AND ASSOCIATE DIRECTOR OF THE INSTITUTE FOR NATIONAL SECURITY AND CYBERSECURITY EDUCATION & RESEARCH AT THE TEXAS A&M UNIVERSITY SYSTEM, UNITED STATES OF AMERICA |
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| **KAZEM GHARIB ABADI** | PERMANENT REPRESENTATIVE OF ISLAMIC REPUBLIC OF IRAN TO THE INTERNATIONAL ATOMIC ENERGY AGENCY AND COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION. MINISTRY OF FOREIGN AFFAIRS, ISLAMIC REPUBLIC OF IRAN |

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| **ROBIN GRIMES** | MINISTRY OF DEFENCE NUCLEAR CHIEF SCIENTIFIC ADVISER. THE ROYAL SOCIETY AND IMPERIAL COLLEGE LONDON, UNITED KINGDOM |
| **RAFAEL GROSSI** | PRESIDENT REVIEW CONFERENCE 2020, TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS. MINISTRY OF FOREIGN AFFAIRS, ARGENTINE REPUBLIC |
| **JILL HRUBY** | SAM NUNN FELLOW, NUCLEAR THREAT INITIATIVE. FORMER DIRECTOR SANDIA NATIONAL LABORATORIES, UNITED STATES OF AMERICA |
| **RAYMOND JEANLOZ** | CHAIR OF XXI EDOARDO AMALDI CONFERENCE AND OF THE COMMITTEE ON INTERNATIONAL SECURITY AND ARMS CONTROL AT THE NATIONAL ACADEMY OF SCIENCES. UNIVERSITY OF CALIFORNIA BERKELEY, UNITED STATES OF AMERICA |
| **CAROLINE JORANT** | FOUNDER STRATEGIE DE DEVELOPPEMENT ET REGLEMENTATIONS INTERNATIONALES CONSULTING, FRANCE |
| **C. S. ELIOT KANG** | PRINCIPAL DEPUTY ASSISTANT SECRETARY OF THE BUREAU OF INTERNATIONAL SECURITY AND NON-PROLIFERATION, U.S. DEPARTMENT OF STATE, UNITED STATES OF AMERICA |
| **VLADIMIR LEONTIEV** | DEPUTY-DIRECTOR OF THE DEPARTMENT ON NON-PROLIFERATION AND ARMS CONTROL OF THE MINISTRY OF FOREIGN AFFAIRS, RUSSIAN FEDERATION |
| **LI HUA** | DIRECTOR OF THE SCIENCE AND TECHNOLOGY COMMISSION, CHINA ACADEMY OF ENGINEERING PHYSICS (CAEP), PEOPLE'S REPUBLIC OF CHINA |
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| **DAVID NUSBAUM** | PERMANENT REPRESENTATIVE OF ISRAEL TO THE INTERNATIONAL ATOMIC ENERGY AGENCY AND COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION. ISRAEL ATOMIC ENERGY COMMISSION, ISRAEL |
| **SERGIO ORLANDI** | HEAD OF THE PLANT ENGINEERING DEPARTMENT. INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR (ITER), ITALY |
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| **YOUNG-HO PARK** | DIRECTOR OF THE KOREA PEACE FOUNDATION. KOREA INSTITUTE FOR NATIONAL UNIFICATION (KINU), REPUBLIC OF KOREA |
| **WOLFANGO PLASTINO** | SCIENTIFIC SECRETARY OF XXI EDOARDO AMALDI CONFERENCE AND OF INTERNATIONAL SECURITY AND ARMS CONTROL WORKING GROUP AT THE ACCADEMIA NAZIONALE DEI LINCEI. ROMA TRE UNIVERSITY, ITALY |
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| **ALICIA SANDERS-ZAKRE** | POLICY AND RESEARCH COORDINATOR, INTERNATIONAL CAMPAIGN TO ABOLISH NUCLEAR WEAPONS (ICAN) |
| **CARLO SCHAERF** | MEMBER OF THE BOARD OF XXI EDOARDO AMALDI CONFERENCE AND OF INTERNATIONAL SECURITY AND ARMS CONTROL WORKING GROUP AT THE ACCADEMIA NAZIONALE DEI LINCEI. TOR VERGATA UNIVERSITY, ITALY |
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| **TIBOR TÓTH** | EXECUTIVE SECRETARY EMERITUS OF THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION (CTBTO) |
| **EDOARDO VESENTINI** | MEMBER OF THE BOARD OF XXI EDOARDO AMALDI CONFERENCE AND OF INTERNATIONAL SECURITY AND ARMS CONTROL WORKING GROUP AT THE ACCADEMIA NAZIONALE DEI LINCEI. POLYTECHNIC UNIVERSITY OF TURIN, ITALY |

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ROME
WWW.LINCEI.IT

SCIENTIFIC SECRETARY

PROF. WOLFANGO PLASTINO
WOLFANGO.PLASTINO@UNIROMA3.IT

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