NESST:

A Nuclear Energy Safety & Security Treaty

Separating Nuclear Energy from Nuclear Weapons.

Brendan McNamara

Leabrook Computing,

October 2010

brenergy@gmail.com **Mobile: 07768 748217**

NESST: A Nuclear Energy Safety & Security Treaty separating Nuclear Energy from Nuclear Weapons.

Brendan McNamara, Leabrook Computing, July 2010

brenergy@gmail.com

The need to manage all radioactive materials associated with Fission and Fusion energy is matched by the need to completely separate civilian energy programmes from the production of nuclear weapons. The Nuclear Proliferation Treaty (NPT, 1968) muddles these issues together and it's politically restrained monitoring through the IAEA is clearly ineffective at regulating either. The Treaty obligations rely on trust and carry no specific or graduated penalties for breaches of the trust. Historically, the responses to breaches have all included the options of nuclear attacks, the worst possible solution. There are no requirements that weapons facilities be inspected, merely that civilian facilities with the potential to support weapons be inspected periodically by the IAEA and at their convenience. The realities of safety in nuclear plants are that 24X7 monitoring of personnel and equipment is actually essential, as it is in any large chemicals or petroleum facility, but this is not demanded in the Treaty. This was a key failure at Three Mile Island. There is a clear case for making a new Nuclear Energy Security Treaty (NESST) which is rigorous, enforceable without violence, and separate from the political quagmire of nuclear weapons. As nuclear power is spreading rapidly around the world with 230 reactors ordered by 2020 and thousands to come by 2050 it is now urgent to open this discussion with the clear mutual intent to apply its provisions retrospectively.

Is a NESST agreement possible? The toughest element to accept is that of penalties and why they are necessary. Nuclear power stations are built with a 50-60 year service life. In the next 50 years we may expect dictators and theocracies to be replaced at least twice and democracies about 10 times. Each new government will have the option of continuing, rejecting or subverting its Treaties. Already in the 21st century, one major democracy rejected the United Nations, the Geneva Convention, international law on invasion of other countries, and international law on torture, setting new precedents. The rise of Islamic terrorism has included citizens of western countries in acts of violence and sabotage. Treaties on the handling of radioactive materials must transcend such arbitrary behaviour and meet a very high standard of effectiveness. Our political systems are so varied that it is unlikely that sufficient powers or enforcement capabilities could be assigned to a single world authority for this purpose. However, it is obvious that the people with the greatest interest in a country's nuclear mismanagement or attempts to divert materials to a weapons programme are its neighbours, so some devolvement of responsibilities is necessary. Neighbouring countries also have the best opportunity to collaborate in the monitoring of all civilian nuclear facilities, monitor trade and travel, close borders, cut energy supplies, apply financial penalties, or take other measures using the NESST principles for such actions. The possibility that energy supplies may be cut is far more potent than any other economic sanctions. All facilities would have resident NESST inspectors, with appropriate international training, from several or all of the countries in a Region. IAEA inspectors would be permitted to visit at any time. The politics of penalties becomes feasible on a region by region basis.

The Baltic Region is a convenient example which fits the NESST scenario very well. All the countries would like to use nuclear power and reactor vendors have already said they cannot take back nuclear wastes and that the country or Region must handle them. Finland is building the first of a kind of the Areva EPR reactor and has also constructed a deep geological disposal site to accept spent fuel. Sweden is also contemplating a Deep Disposal facility. Poland is a major coal burner in the EU, has interest in a first round of 5 nuclear reactors, and has signed a collaboration agreement with the USA. The Baltic States would like to connect and be part of this nuclear energy group. The region would eventually benefit from an enrichment plant and a fuel recycling plant to service the 50-60 reactors in the region by 2050.

Nuclear fuels provide millions of times more energy per tonne than fossil fuels and are therefore cheap, but they are also much less abundant so supplies come from a small number of countries. The nuclear technologies are far more sophisticated than those for fossil fuels and are correspondingly expensive. Thus, not every country can have or afford a complete suite of technologies from Uranium Mining to Enrichment to Fuel Fabrication to Spent Fuel Recycling to the Burning or Management of radioactive wastes. The geographical spread of resources and facilities therefore provides many choke points where penalties and restrictions can be imposed. Global trade, finance and banking, environmentalism, and mobility of people have already diluted sovereignty and increased cooperation between nations. The NESST agreements would place separate responsibilities on every part of the civilian nuclear enterprise.

This is quite different from the protectionist times of the cold war when the NPT was created, arising from the Atoms for Peace programme. The terms of the NPT are directly opposite to the earliest view that all knowledge of nuclear technologies should be kept secret, even though it was already too late for that.

Somewhat absurd rights were declared as follows:

NPT Article IV: Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty.

So, any country could sign the Treaty and claim the inalienable right to any or all of the materials and technologies of nuclear energy. It is then straightforward for a later administration, which feels threatened or has been attacked on all sides, to set up secret weapons facilities as they wish and deny it as they will. This is almost precisely the scenario unfolding in Iran today. It is more likely that their long game is to have real or virtual bargaining chips to improve their position in the world.

The NESST agreement, primarily among neighbouring countries, would replace such rights by **permanent responsibilities** to keep any and all components of nuclear energy systems completely secure using any surveillance measures agreed for that region. Fission power is good for several thousand years at least, so 'permanent' implies this timescale. We do not want to litter the planet with polluted sites, so tight control of nuclear materials is needed to keep sites active for thousands of years. NESST is needed to meet this level of diligence.

Let us examine some of the possibilities for diversion of civilian nuclear materials and the steps and NESST penalties for infringements:

Uranium Mines

Uranium mines are the start of the fuel cycle. Up to 1 million tonnes (1Mt) of rock may have to be moved to extract the

85,000t of 1% Uranium ore needed for the initial fuel load for a 1 Gigawatt (1 billion kilowatts of electricity) nuclear reactor. The Uranium is extracted from the rock and turned into a Uranium Oxide, or 'yellow cake' as the final product. The 850t of ore finally yields 72 tonnes of 5% low enriched Uranium (LEU) for reactor fuel. The scale of the mining activity is substantial and, in these days of satellite surveillance, it is hard to hide a mining activity on this scale. However, only 2.7 t of natural Uranium are needed by a country like Pakistan, which still mines about 45t per year, and was willing to use centrifuge enrichment to extract the 90% pure U-235 for making one nuclear weapon. This is quite a small amount and so safeguards are needed at the mines on the production and sale of yellow cake and its transport to approved enrichment facilities.

The NPT allows any compliant country to hold up to 10 tonnes of natural Uranium without special safeguards, which is already far too much. Nothing is said about the mining or use of Uranium deposits from a country's own resources, but NESST would put all known and discovered Uranium sources into the regional agreement. Unreported resources would constitute a breach of the agreement with potentially severe penalties by the neighbours. The price of Uranium is set to rise strongly with a strong rise of nuclear energy as fossil fuels decline or are avoided. Several countries are stockpiling safeguarded Uranium at the low price, but the only valid destination for fresh Uranium is an Enrichment or Fuel Fabrication Plant to prevent stockpiling.

In the event that material from a particular mine has been diverted then a chain of penalties could begin. All shipments en route around the world from this mine would be impounded for inspection. Regional and international inspectors would close and inspect the offending mine and expand the audit within the offending country or region as appropriate. The client for diverted materials would be identified and the Region of the offender would begin local proceedings against the client or client state.

Enrichment

Natural Uranium Oxide is converted to Uranium Hexafluoride, UF_6 , which is solid at room temperature and sublimes at 56.5^oC. This vapour is spun through a chain of centrifuges and recycled till the final enrichment is at the desired 4.95% enrichment for fuel fabrication. It takes 11t of natural Uranium to produce 1t of enriched fuel along with 10t of Uranium depleted to 0.275% ^{235}U, using 25MWhrs of electricity to drive the centrifuges. This process is up to 50 times more efficient than the earlier Gas Diffusion plants which are now almost completely phased out.

The Depleted Uranium has long been described as a waste product but, as we will see, all of it is potentially reactor fuel and should be safeguarded with meticulous accounts and monitoring of any movement of nuclear materials. It is ridiculous to divert it for use in munitions, wing weights or other such applications that would not be permitted by NESST.

A typical new enrichment plant is American Centrifuge's Piketon facility with 1400 centrifuges able to produce 760t of fuel for 38 1GW reactors per year, and costing $3.5Bn. The plant will process almost 700t per month of fresh Uranium. The centrifuges spin at 100,000 rpm and have to be continuously monitored to avoid explosive failure of bearings or seals. Fast reactors, research reactors and other high performance reactors would need 20% enrichment. Consider a scenario using a short train of centrifuges separated from the main operation to divert and further enrich materials into a weapons programme in a 5 year plan: Only 4.54t of LEU at 4.95% are needed to produce 1t of legal HEU at 20% ^{235}U and put 3.54t depleted to the natural Uranium level of 0.7% back in stock. Beyond that, a tonne of HEU can be enriched to 177kg of weapons grade (90%) Uranium and 823kg depleted to LEU grade at 4.95%. At the end of this secret operation only 177kg of material is missing, a 35cm^3 volume of Uranium Hexafluoride, and the rest looks like natural Uranium or HEU. This illustrates the accuracy needed to monitor accounting procedures and material flows to detect any diversion.

It is clear that the only truly secure monitoring of an Enrichment plant will be 24X7 with automated reporting to a central database. It is only the remote monitoring and reporting step that is additional to monitoring for plant safety. Corporations and employees cannot, in principle, be trusted any more than countries, politicians and generals, so all enrichment plants need this level of safeguards. At a minimum, NESST would require that any plant suspected of diversion would be shut down promptly for an immediate audit. All shipments to and from this plant would be impounded wherever they were in the world as first steps to isolate the system in breach of NESST. Internal investigations would be made into the actions of the regional NESST inspectors. Several regions could become involved, expanding the responsibilities from country to Region to Regions to the IAEA level of world authority.

Fuel Fabrication.

Enriched Uranium Hexafluoride may be used directly in advanced reactors such a Molten Salt Breeder or a Fusion-Fission Hybrid reactor, or must be converted back to Uranium Oxide for PWR reactor fuel or to metal, Uranium Carbide or Nitride for Fast Reactors. The movement of materials through the plant is not a continuous flow so there are many interim storage steps at which diversions become possible.

When Plutonium fuels such as MOX or mixed oxides are to be fabricated then the input may be quite radioactive. Thorough control and monitoring of materials will already be designed into the systems on safety grounds. Monitoring for Safeguards is again a small addition. A similar range of inspections and penalties as used for enrichment plants would be applied in the event of any breach of NESST.

Spent Fuel Recycling

About 20t of spent fuel is extracted per year from each PWR reactor and replaced with fresh fuel. The spent fuel is highly radioactive and must be cooled for 5-10 years at the reactor site before it can be moved on to recycling in robust radiation, fire and collision proof caskets. The materials could be used to make a dirty bomb, though at great hazard to the makers. Stealing such materials seems to be far beyond the capabilities of a shoe bomber, but spent fuel in transit should have an armed escort. The NPT has no such rules.

The latest recycling plant was designed by AREVA and Japan for the Rokkasho site. It will have 6 units able to process 800t per year, including legacy spent fuel from 40 years of nuclear power in Japan. By 2050, some 90 recycling units around the world would be needed, region by region, to maintain 3500 reactors. The scale of safeguards for recycling will grow with the reactor fleets, so a NESST agreement is an essential part of this framework.

A recycling plant chemically separates spent fuel into unused Uranium isotopes (93%), Plutoniums and higher Actinide fuel components (2%), and the Fission Products (FPs) isotope components (5%). The chemical separation of Plutoniums is much simpler and faster than centrifuging Uranium. Only 5kg of 95% pure ^{239}Pu is needed for a nuclear weapon, though rather more with the mix of Plutonium isotopes created by long burns in a reactor, so it is important for safety that processing be done in small batches. Plutonium oxide pellets are inserted along with standard enriched Uranium oxide pellets to make up MOX fuel. The 1 tonne per reactor year of Fission products are radioactive and about 20% of the isotopes have decay times of up to 200,000 years, making them a very long term hazard. The more radioactive isotopes with short decay times could be combined with chemical explosives to make dirty bombs. Such a weapon could make a city uninhabitable for 100's of years. So, every gram of material must be monitored through the plant. The recycling plants offer the best opportunities for diversion of weapons grade materials and require the most stringent safeguards.

Since there would be no more than one or two recycling plants in a Region a breach of NESST by a recycling plant would affect the whole region with penalties. All incoming Uranium, fuel, or even electricity could be stopped by bordering Regions. A full investigation of the Region and all the NESST inspectors may be triggered.

Fission Product Waste Disposal

The modest volume of Fission Products, containing most of the radioactivity from spent fuel, needs special treatments at the end of the chemical separation process to make them safe over geological timescales. The primary method proposed is to vitrify all the solids in impermeable form and bury them in deep disposal mines in places which are unlikely to be geologically sound across ice ages. It may be desirable to have inventory lists which can survive for such lengths of time. No geologically safe disposals have yet been built which meet this requirement. Needless to say, the disposal system needs more precise accounting than a county landfill site.

There is a far more appealing alternative, using neutrons from small Fusion plants, installed at the recycling plants, to actually burn these wastes into non-radioactive elements. Such powerful Fusion neutron sources would be quite flexible in what they could burn and would require accurate accounting for all materials. There would then be little need for geological disposal of high level radioactive wastes.

Tiny amounts of long lived wastes can diffuse into the structural materials of a nuclear reactor. It seems uneconomic to separate grams of isotopes from tonnes of material, so decommissioning of each nuclear plant does leave a legacy of mildly radioactive materials which could be diluted below natural radioactivity levels for disposal. In a more highly robotic age such materials could instead be re-used without harm to mankind. Again, permanent disposal is not necessary.

Emerging Generation IV Technologies

Fast reactors can use Depleted Uranium as feedstock for fuel breeding. Natural Thorium is 100% ^{232}Th which is not fissile but, in a reactor, can be transmuted to another Uranium isotope, ^{233}U. This fuel breeds hardly any Plutonium at all, cutting out the simplest route to nuclear weapons. Spent fuel must still be recycled to remove FP wastes and would need a steady supply of Thorium. NESST will be expanded to apply to all new nuclear technologies which involve fissile materials.

The Role of Fusion

Fusion produces almost 20 times as many neutrons per tonne of fuel as does fission. The neutrons are as useful as the energy they carry and can be used to burn long lived nuclear wastes or generate fissile material from Depleted Uranium or Thorium at 10 times the rate of a Fast Reactor. The UK, for example, already owns enough Depleted Uranium to support an all electric Britain this way for 500 years. These capabilities could now support the Fission industry through the coming period of rapid growth in nuclear power and solve the long term waste disposal problem. Moderate size Fusion plants will be able to work in hybrid fashion as a Fusion core to a liquid fuelled Uranium or Thorium blanket reactor which would be far more efficient than a Fast Reactor. This implies that such Fusion applications must be included in the NESST agreements with the same levels of 24x7 monitoring. The multiple advanced technologies used in a fusion plant of any kind are hard to acquire and difficult to implement in secret, presenting a high technologies barrier to secret usage.

Nuclear Weapons

What about the control of nuclear weapons? The NESST goal is to separate the management of nuclear energy from military programmes but would include clauses to forbid new weapons programmes even if all NESST facilities were operated correctly. NESST would apply to facilities in each region which are declared to be only for civilian purposes. Internal diversion of materials from these facilities, or misuse of them for military purposes, would be breaches of the NESST agreement and would provoke the NESST penalties on that country or region. Any attempt by a country or region to start a new weapons programme would also be seen as a major NESST breach and provoke the maximum penalties on civilian uses without appeal.

Under NESST no facility would supply or support any facility which is not part of a NESST agreement. This means that no NESST mine would supply Uranium and no NESST fuel factory would supply fuel. NESST recycling plants may accept spent fuel or decommissioned weapons grade materials from military facilities but all the materials would be retained and nothing returned.

NESST countries would also prevent shipments of any nuclear materials from entering their territory from a non-NESST supplier. All such materials would be declared illicit and impounded. This will not shut down secret deals between countries but will raise further barriers to weapons development or to the build up of weapons stockpiles.

Difficult Regions

The Baltic region described earlier has members who are already partners within the EU, so NESST appears as just an efficient nuclear management process. It could be an excellent stage in which to develop all the details of NESST.

How would it work with a group of neighbours with many disputes? Let us contemplate an East Mediterranean Region (EMR) defined as Turkey, Syria, Jordan, Lebanon and Israel. They are all actively pursuing nuclear energy in various ways. Israel is a nuclear weapons state which has refused to sign the NPT, has bombed actual or suspected research reactors in Iraq and Syria, and frequently threatens Iran with similar attacks. Nevertheless they are showing increasing interest in nuclear energy. Israel is still in conflict with all these neighbours and the best early concession which may be sought is for them to agree not to bomb civilian nuclear facilities in neighbouring countries that are fully compliant with a NESST agreement. In return they may be offered membership of the regulatory services of the local NESST agreement to ensure that the agreement is effective. There is no NESST requirement that Israel disarm, only that all civilian programmes are completely cut off from existing military ones in Israel or anywhere else.

Meanwhile, Jordan has signed the NPT and is planning a civilian nuclear energy programme based on the fact that it has significant Uranium ore deposits and also extensive Phosphate deposits with 0.1% traces of Uranium. This is enough to supply the Region with 50 GWy-e for 600 years. Israel has objected to Jordan opening Uranium mines and has gained support from the USA, who is not a neighbour in this region. Under NESST, Jordanian Uranium mines would be unable to supply Israel with Uranium if it remained a non-member. Turkey is an NPT signatory, is seeking EU membership and is negotiating to build several nuclear power stations. The region may well trust Turkey to establish a recycling plant and disposal sites as part of the regional facilities. Syria has also proved to be a difficult neighbour but is aware that nuclear energy may become a necessity. Their oil production is now falling rapidly but significant gas production is now in place. Syria has no high tech industry, making the presence of any current nuclear facilities a source of suspicion. The region may not agree to Syria having anything but a set of power stations and thereby being highly dependent on NESST members to fuel them and manage wastes. Enrichment and fuel fabrication plants may be best placed in separate countries in the region or even outsourced to Eastern Europe.

Self interest in the need for secure and reliable energy, without threats from neighbours, may be sufficient for even such a fractured set to become neighbours in a NESST agreement. The EMR is very much poorer than the Baltic region and even Israel is highly dependent on US aid. Social conditions are also quite different and many Inspectors may be susceptible to bribery or corruption. In the interests of neighbouring and other Regions it would be necessary to have an IAEA inspector as a permanent member of every NESST team. In such a region the inspectors may even have expanded powers to shut down plants without further discussion. Restricting or otherwise interfering with the work and role of inspectors would be a NESST breach and would trigger a chain of sanctions such that reactors could be out of fuel within a year.

Concluding Remarks

It was widely known in the mid 1970s that Libya, Syria and Pakistan had secret nuclear programmes. I visited Pakistan in 1977 to lecture on Fusion at an international summer school and it was quite evident, from the reactions of our hosts, that a significant nuclear programme was operating and most probably on weapons. I left Pakistan the day before Bhutto and his cabinet were all arrested. These proliferation efforts were clearly part of the ongoing ‘real politik’ games of the time and I hoped were none of my business. The results of these adventures are now stuff for think tanks.

Current thinking on proliferation and nuclear energy technologies is only incrementally different from the current NPT regime, and despite many new initiatives and multinational discussions still relies on confrontation and military options as the primary fix. The NESST proposal is a different structure entirely, though useful debris from the NPT story can be reused. The penalties are proportional, all focus on nuclear energy not on generalised sanctions, and are operated through significant choke points in the global system.

The technologies for measuring, detecting and monitoring nuclear activities have advanced greatly since the NPT was constructed. All of these are needed within the NESST framework to prevent accidents and diversions, not to respond to events which have already happened. Looking for radiation leaks is an important part of continual safety checks but could also detect secret pipework. Under NESST, the barriers to illicit use of materials become almost insurmountable and carry quite drastic energy penalties. Nuclear emergencies can still happen, but the first line of response would be from Regional emergency teams, backed up by the NESST investigative capabilities.

Nuclear energy has proved to be reliable, safe and cost effective when operated well. Human behaviour is not nearly so reliable and requires multiple checks and balances and overriding penalties for proscribed activities. Self policing by industries or even countries has proved inadequate on many occasions. For example, so called ‘Regulatory Capture’ of government agencies by the oil industries contributed to the Gulf of Mexico disaster. Such action in a NESST Region would prove far less likely. Only a highly cooperative security regime can meet all the requirements. Because of its very high profile with clearly understandable goals, nuclear energy may well have the first such regime to succeed. This may serve as a model for further agreements on sustainability of fisheries, forests, populations, carbon emissions and the many other problems of our own making. NESST will clear the way for nuclear disarmament negotiations in a world of real mutual security for nuclear energy.

Author

Brendan McNamara worked on Fusion Theory with AEA Technology, Culham (1961-71) and at the Lawrence Livermore National Labs in California (1971-85). He also ran a series of Plasma Colleges at the International Centre for Theoretical Physics,Trieste, 1974-84. He was Exec. V.P. of the Von Neumann Supercomputer Center in Princeton (1985-88) and now operates Leabrook Computing from the UK as an Energy Consultancy. Many of his works on Fusion and Fission may be found on www.ralphmoir.com.