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Nuclear Safety and International Governance: Russia and Eastern Europe

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INTRODUCTION

The nuclear industry, which emerged in an atmosphere of post-war euphoria with the promise of infinite utility at virtually no cost, has been increasingly controversial in many states over the last thirty years. As the unrealistic nature of the early claims became clear, questions began to be asked in the West as to the proportionality of the perceived risks and benefits and the adequacy of arrangements for control of the industry in the public interest (Del Sesto 1982). The industry, naturally convinced of its case, responded defensively to the developing mood of scepticism and public unease, leading it to resist scrutiny and to suppress information which could subsequently be used against it. Plants tended to operate in relative isolation, with the result that there was no pooling of operating data from which lessons could be drawn and disseminated throughout the industry.[1] Regulation, initially combined institutionally with promotion in an inherent conflict of interest, developed continually in its comprehensiveness and complexity in response to public pressure, but did not generally win the trust of a citizenry sceptical of its eventual independence (Duffy 1997, Schnaiberg 1982). The international dimension, initially intended to balance promotion of the civilian industry with non-proliferation of weaponry, only latterly developed a concern with operational safety (Szasz 1992).

National reviews of nuclear governance arrangements were prompted by accidents, beginning with the Windscale fire in 1957 which gave rise to the independent Nuclear Installations Inspectorate (NII) in the UK. The 1979 accident at Three Mile Island in America initiated a re-evaluation of both governance and operational practices in the West due to the extent of the resulting inquiry and the publicity accorded to its conclusions. The concept of safety, previously defined in purely technological terms, began to undergo a significant revision in the wake of the TMI accident analysis, which highlighted the critical role of human actions and the man-machine interface in turning a minor mechanical failure into a near-disaster (Brookes 1982). National regulation was modified in many nuclear states in an attempt to reflect new understanding and the basis for international guidance was similarly broadened. Yet, the technological focus remained strong amongst a profession dominated by engineers. The industry, particularly in America, sought to address the prevailing lack of communication between plants, which had also been identified as a significant factor in the analysis of TMI. In the American context, where, as private enterprise, the industry had an established identity separate from that of the state, the need to secure its future in the face of public opposition led to the development of self-regulation (Rees 1994).

[1] This has been referred to as the 'fossil fuel mentality', an attitude which does not allow for the uniqueness of

The analysis of the 1986 Chernobyl disaster emphatically confirmed the insights gained from TMI, while also demonstrating the extent of transboundary impacts in the event of a very serious accident (Z Medvedev 1990). This gave significant additional impetus to the regulatory revision already underway at national and international levels, although it did not result in a clear international consensus on regulatory strategy or a uniform understanding of the nature of risk and, conversely, of safety. The appropriate regulatory balance between transparency and discretion remained as controversial as ever, with each state choosing its own position on the spectrum in accordance with its national political culture. The implicit trade-off between effectiveness and public accountability became an issue, particularly in relation to the developing self-regulatory regime in America. The risk contributions of human factors and management issues have been increasingly recognised as important, but their treatment has remained problematic in relation to the trend towards risk quantification. In a political environment where risk uncertainty is unacceptable, it is also becoming increasingly apparent that it is inherent and therefore unavoidable, leading to fundamental contradictions in public policy.

Ironically, the lessons derived from Chernobyl had less impact on nuclear governance in the Soviet Union, where the consequences were primarily felt, than they had in most other nuclear states (G Medvedev 1993). Those in control of the industry remained at liberty to exercise complete discretion to conceal vital health and safety information in their possession from citizens and others (Yaroshinskaya 1995). At the international press conference convened after the accident AM Petrosyants, Chairman of the Soviet Union State Committee on the Use of Nuclear Energy (Gosatom), revealed his priorities with the statement that 'Science requires victims' (G Medvedev 1991). Chernobyl served to highlight the fundamental flaws of a system grown increasingly monolithic and, ultimately, to hasten its downfall.

The regulatory response to Chernobyl was still in progress in the West, with problems recognised but not yet adequately or consistently addressed and public trust still lacking, when the collapse of the Soviet Empire abruptly presented the international community and the nuclear industry with its most significant challenge. The disintegration of the Eastern Bloc resulted in international access to previously closed sites, including nuclear facilities, where the legacy of decades of central planning combined with political repression and suppression of information was exposed. The problems of technological determinism, disregard for human factors, lack of safety culture, equation of the interests of the nuclear industry with those of the state, overemphasis of benefits with underestimation of costs and risks and lack of communication, all of which have to a variable extent plagued the industry in Western states (Rees 1994), were revealed to have been at their most extreme under the Soviet regime. With no checks and

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nuclear installations. (Rees 1994).

balances, no independent counterweight and no public voice to heed, the failure of governance, according to many of those most intimately involved, had been virtually complete (G Medvedev 1991).

Many newly independent states, often with few resources and little experience of nuclear governance, welcomed the prospect of international intervention, although Russia itself remained reserved. Central and Eastern Europe and the FSU became a forum for the simultaneous application of different approaches based on different views of nuclear safety. The attempts to address the problems have involved the whole-scale revision of governance arrangements, arguments over the nature of safety and means of achieving it, a vast range of practical initiatives based on different assumptions, and a great deal of money. The rather chaotic nature of the process has been greatly exacerbated by the destabilising effect of an abrupt transition from the extreme of central planning to the opposite extreme of unregulated capitalism, which has been uneven in its impact. The Russian economic crisis of 1998 has been the culmination of the resulting financial difficulties.

Consensus, particularly between donors and recipients of assistance but also amongst donors and amongst recipients, has been much more difficult to achieve than was initially envisaged. Indeed, divisions on some issues, for instance the desirability of plant closure, are becoming more apparent with time. The prevailing assumption amongst donors that a Western approach is objectively correct and therefore universally applicable has been problematic in this regard. The implication of this assumption is that the West has solved its nuclear conundrums when in some cases their extent is often only now coming to light. The specific point of contention has been the merit of using a set of comprehensive technical requirements, developed incrementally under conditions of political and socio-economic stability, as the reference criteria by which plant safety is to be judged. Insistence on this point does not accord highly trained Russian technical specialists much respect, and fails to recognise the contextual relevance of the prevailing economic, political and social circumstances. The fact that the instability of these contextual factors cannot help but contribute to the overall risk needs to be addressed by both sides in the search for a workable consensus.

This monograph will examine the range of initiatives being field tested in the former Eastern Bloc, and the assumptions underlying each approach, in order to compare their effectiveness where evidence is beginning to emerge. The means by which the extensive involvement in Eastern Europe of governments and the industry itself has precipitated the development of an increasingly international nuclear governance structure will be discussed. Finally, the issues raised by the advent of an international structure, particularly the potential trade-off between effectiveness and accountability and the balance between formal regulation and informal control, will be analysed.

The study will begin in Chapter 1 with a review of the role of nuclear power in the energy sector of the Soviet Empire, noting the aspects of the central planning system which led to the development of physical defects during an extremely rapid construction programme. The means of implementing political priorities in that industry will be discussed, with emphasis on the profound effects of structural incentives for the distortion and suppression of information. The response of the impenetrable and unaccountable nuclear bureaucracy to the regulatory challenge posed by various serious accidents, including Chernobyl, will be shown to amount to regulatory failure.

Chapter 2 will assess the effects of the political and economic collapse of the Soviet Bloc on the energy sector throughout Central and Eastern Europe and the FSU, discussing the increased nuclear dependency in many states during the 1990s. This period covers the chaotic transition from the extremes of central planning to the extreme of unregulated capitalism, which had a predictably severe effect on the economics of energy generally and on the nuclear industry in particular. The process of prioritisation under conditions of severe resource shortages and the proliferation of novel regulatory bodies, which may mirror in practice, if not as officially constituted, the conflict of interest inherent in early Western or current international arrangements, are examined.

The third Chapter outlines the initial international response to the increasingly apparent problems in the nuclear sector, explaining the basis for the strategy proposed in 1992. It then goes on to profile the established international actors, such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) at the OECD and the European Commission, and to detail the arrival of new bodies such as the World Association of Nuclear Operators (WANO). The agenda and priorities of each organisation are compared and their modes of intervention introduced.

Chapters 4 through 7 each deal with one mode of intervention, assessing the initiatives undertaken by those addressing that particular aspect. Chapter 4 concentrates on technological intervention, which has been the primary concern of the majority of players and has absorbed by far the largest share of available resources. Both the necessity and the shortcomings of this traditional engineering approach to safety are identified. Chapter 5 addresses the range of human factor initiatives, which have largely sprung from the analyses of TMI and Chernobyl, discussing sometimes controversial operational and management issues and placing considerable emphasis on means to encourage the development of safety culture. Chapter 6 covers the role of the rule of law generally and the development of formal nuclear regulation specifically, identifying the major barriers to the rapid establishment of credible regulatory regimes. The importance of the political and legal legacy from the Soviet era is discussed. Chapter 7 deals with the development of formal and informal mechanisms of governance at the international level, highlighting the problem of national sovereignty in relation to the development of binding international controls on an industry with a military heritage. The potential role of self-regulation and the involvement of the international insurance markets are discussed in this context, with consideration of the implications for public accountability in the industry globally.

Chapter 8 covers the long-running and increasingly acrimonious debate over plant closure, examining in detail the very real economic and social barriers to closure. Many of these are structural, requiring long-term shifts which can only occur with financial support, and must therefore be considered as part of the negotiating process despite inevitable opposition. The relativity of risk perception, as affected by economic transition, is particularly relevant as it highlights the issues of the continuing debate as to the nature of risk. Finally, the damaging brinkmanship which has developed from the clash of political perspectives will be set in context.

1. POWER AND EMPIRE

1.1 Energy Crisis and the Role of Nuclear Power in Soviet Energy Policy

Energy assumed its central role in Soviet central planning with the advent of modern oil resource development from the late 1950s (Gustafson 1989). Within a few years, the USSR was using its natural abundance of energy – oil as well as coal and gas – both to develop its own industrial base and to underwrite economic development throughout the satellite countries of the Council for Mutual Economic Assistance (CMEA).[2] Industrialisation was paramount in the cold-war race for supremacy, hence ambitious targets for the development of productive capacity were set by the central administration in successive five-year plans. These production goals were matched with energy projections, which then became the basis for five-year supply requirements. The five-year goals would then be broken down into annual and monthly targets by negotiation between ministerial representatives, hence the short-term interests were over-represented at the implementation phase.

Both the long- and short-term targets imposed were frequently ill-founded due to the lack of accurate information upon which to base them. Information passed vertically within institutions, but not often between institutions even where it was necessary. The integrity of even such data as was passed on was compromised by the systemic incentives to misreport information. The priority accorded to fulfillment of annual and even monthly plans was reflected in the general wage structure for all state employees from labourers to ministers, with bonuses for meeting targets being a significant fraction of annual salary whether or not the targets were in any sense achievable. Directives from above were therefore distorted at every stage of execution both by unavoidable practical considerations and the dominance of short-term objectives. The reported results of plan implementation were then distorted in return, in order to claim compliance. Constructive adjustment of targets in the light of experience was therefore virtually impossible due to the lack of accurate feedback.

The energy sector was developing rapidly, requiring the planning system to be informed and to evolve in a manner consistent with that information. However, the myriad hierarchical institutions representing different fuel industries were strictly compartmentalised according to very narrow objectives. The focus on core tasks was paramount while central oversight and co-ordination were weak, preventing priorities from being aligned for the achievement of composite objectives.

Energy plans concentrated on increases in supply from well-established producer regions rather than broadening exploration, hence Siberia became the centre of the oil industry, which was in turn the centrepiece of the energy sector. Increases in energy demand led relentlessly to increases in production targets for the Siberian oilfields, although there were considerable practical difficulties involved in transporting necessary inputs as well as output over the long distances between Siberia and the centres of demand in Europe. The rate of increase of supply could not keep pace with accelerating Soviet and CMEA demand and so production targets for the over-exploited fields became progressively harder to meet despite increased investment.

The oil shocks of the 1970s had presented the oil-exporting Soviet Union with a golden opportunity to emerge from relative economic isolation and capitalise on the revenue-generating potential of the natural resource base. Oil exports rose from 30 per cent of hard currency income to 80 per cent between the mid 1970s and the mid 1980s, but heavily subsidised exports to CMEA countries were equally important as a means of ensuring Eastern Bloc consolidation through economic leverage. The pressure on Siberian supply was therefore continually increased despite the rapidly escalating costs of production. Since this could not continue indefinitely it was decided to develop a long-term strategy based on coal and nuclear power to serve domestic and CMEA needs, with reliance on gas in the interim, while selling oil on world markets.[3]

The Soviet Union had begun to develop nuclear power in the 1940s and 1950s, but it still made only a small contribution to total electricity generated well beyond the time at which it had become fashionable in the West. The early 1970s saw the first 1000 MW units come on line, and the tenth five-year plan, spanning the years 1975–80, represented the first strong commitment to nuclear power. The momentum increased thereafter, with the Eleventh Plan (1980–85) calling for an additional 21,300 MW to reach a total of 38,800MW. The plan missed its target by a considerable margin, although the 1980–85 period saw a substantial actual increase of over 12,000 MW on line and much more under construction. The Twelfth Plan (1985–90) called for a 250 per cent increase in nuclear generating capacity to 69,000 MW, most of which was to be concentrated at large sites averaging 6000–7000 MW (Marples 1986). A large amount of 'shock-work' reactor construction was underway at the time of the accident at Chernobyl,[4] although the actual target was not in any sense achievable in the timeframe proposed.

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[2] The CMEA is the Eastern acronym, while in the West the term was COMECON.

[3] The response to the energy crisis concentrated entirely on supply because energy intensive users were completely insulated from price signals and therefore saw no need to conserve. With energy available at little or no cost to all, and provided in such a way as to make it often impossible to alter usage, there was no prospect of a demand side response.

[4] 'Shock-work' was a Soviet term for rapid construction. As an indication of just how rapid, at the Zaporizhia plant in Ukraine, which was not begun until the late 1970s, five units came on line between 1985 and 1989. A sixth was virtually complete by 1990. The project also involved the construction of the entire city of Enerhodar (Energy Town) within the same timeframe. (Marples 1986).

The intensity of the Soviet construction programme, the dash for nuclear power, was such that supporting infrastructure for housing construction workers and transporting supplies could not keep pace, especially in the Ukraine where the concentration of plants was greatest. The crude conditions at plant sites, and near-impossibility of procuring sufficient materials of even approximately correct specifications, aggravated an already acute shortage of skilled and experienced personnel. The result was the drafting of squads of Komsomol students during their summer break and the recruitment of other unqualified individuals,[5] to the consternation of the experienced engineers and construction managers. The qualified engineering teams would begin one plant then be sent to another to begin again, thereby ensuring that experienced staff could not become truly familiar with any one project and that the learning process would have to be undertaken several times at each plant (Marples 1986:78).

Construction was thus a haphazard and disorganised process undertaken by demoralised managers unable to ensure delivery of requisite materials or expertise and often unable to control their workforce.[6] Many senior engineers and managers complained to their local media representatives of very poor standards of construction for which they bore responsibility in the absence of sufficient authority to ameliorate the situation.[7] The dash for nuclear power, although a considerable feat of engineering in the face of extremely trying circumstances, also highlighted the worst failures of the central planning system. It is not surprising that this approach to nuclear development should have left a legacy of physical deficiencies with potentially serious consequences for the Soviet successor states.

The emphasis on nuclear development led to a rapid increase in the direct export of nuclear power plants to CMEA countries. This might appear to have granted the client states a measure of the independence they had lost through energy dependency on the USSR, but in reality control over nuclear technology and knowledge remained an almost exclusively Soviet preserve. The reactors built in Central and Eastern Europe[8] were either manufactured in the USSR or occasionally produced under Soviet supervision in Czechoslovakia, and the senior skilled engineers at the plants were either Soviets or Soviet-trained. Indeed, nuclear exports allowed a much greater degree of direct Soviet involvement in Central Europe than the exports of cheap hydrocarbons which changed hands at the border (Marples 1986:53).

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[5] Newspaper advertisements in Central Asia requested Tadzhiks to volunteer for work at Ukrainian nuclear plants stressing that no experience was necessary. (Marples 1986:79).

[6] For instance, according to SM Shevchuk (Head of Construction, Rovno NPP), 8000 man-days were lost at Rovno NPP in 1985, largely due to violations of discipline. Many workers were regularly late for their shifts and an increasing number had to be sent to drying-out institutions for treatment for alcoholism. Shevchuk commented that the standard of the work was generally very low. Radio Kiev 03/02/86.

[7] AV Plaksienko (Site Construction Brigadier, Odessa NPP) in *Robitnycha Hazeta* 11/10/84; Chief Engineer, Balakovo NPP in *Sovietskaia Rossia* 30/05/82; IF Shpak (Chief Engineer, Crimea NPP) on Radio Kiev 17/02/86; VT Kizima (Head of Construction, Chernobyl NPP) in *Liternaturna Ukraina* 14/06/74 and *Radianska Ukraina* 29/10/77; L Kovalevska (Local Journalist, Pripyat) in *Liternaturna Ukraina* 27/03/86.

[8] Soviet reactors were constructed in Czechoslovakia, Hungary, East Germany, Poland and Bulgaria. Romania

1.2 Prioritisation in the Nuclear Sector – Location, Technology and Production Targets

The Soviet plans called for nuclear installations to be concentrated in the European part of the USSR, near the centres of demand, although powerful dissenting views called for the construction of massive plants in remote locations, connected via the transmission system (Dollezhal and Koriakin 1979). The prevailing mainstream position was based on the unquestioned assumption that the technology was completely suitable for construction near densely populated areas and, so situated, may be capable of providing district heating in addition to electric power. As such it would be able to further reduce pressure on hydrocarbon requirements.

The western fringes of the Russian Federation and the Ukraine became the major arenas for nuclear development, being both centres of demand in their own right and also obvious conduits for power exports to the CMEA. Lithuania was also chosen for its relative proximity to heavily industrialised areas. In Central Europe Czechoslovakia became a centre for the nuclear industry, partially because of its industrial capability to produce 440MW reactor pressure vessels under Soviet supervision.

Soviet nuclear technology was based on two main designs, each of which was developed and scaled up separately (Z Medvedev 1990). The RBMK is a light-water cooled, graphite moderated, multi-channel boiling water reactor of which there are now sixteen units, all within the former Soviet borders.[9] The VVER design, conceptually comparable to a Western PWR, is a scaled-up version of a nuclear submarine reactor with a compact pressure vessel containing light-water as both coolant and moderator. Initial difficulties in constructing a heavy industrial plant capable of producing large pressure vessels delayed the development of the desired 1000MW VVER reactors, allowing the 1000MW RBMK technology to dominate for a time because the RBMK modular core could be assembled on-site from relatively small component pieces. Only VVER reactors were exported throughout Eastern Europe, initially as 440MW units of the 230 or 213 models and later as VVER 1000s.

The RBMK was frequently favoured by Soviet planners because of its relatively low ratio of heat to electric power produced and the low energy density of its core, which was thought to be inherently safer. It was thought so safe in fact that the designers saw no need for a containment structure, settling instead for a 2.5km building exclusion zone. Its high efficiency ratio was achieved by the use of a single cooling circuit, since that avoided the loss of efficiency inherent in the use of a heat exchanger. Unfortunately

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and Yugoslavia looked to the West for nuclear technology.

[9] In the Russian Federation there are 4 units at Leningrad (Sosnovy Bor), 3 at Smolensk, and 4 at Kursk, with another unit under construction. There are also 3 remaining at Chernobyl (Ukraine), of which 1 is currently

it entailed the passage of radioactive steam through the turbines, with the result that they corroded rapidly, and the building of a huge cooling reservoir, the sediments of which were intended to bind the radioactive particles in the cooling water. The efficiency of the RBMK was also enhanced by the ability to refuel individual channels without taking the reactor out of operation, allowing it to run for two years continuously. The consequences of this aspect of the design are an extremely complex arrangement of pipes serving each pressure tube separately and the need to monitor and control 1700 tubes independently. The risks of both mechanical and human failure are considerably enhanced by such complexity.

The reactor has a positive void coefficient, meaning that if coolant is lost and the residual water is turned into steam, the reactivity increases, thereby raising the temperature, producing more steam and more reactivity in a positive feedback loop.[10] The risk of meltdown or of a prompt neutron surge is therefore much higher than for most other reactor designs. The graphite moderator is also combustible and therefore represents a considerable fire risk if exposed to air. This risk is significant since the core can only withstand the rupture of two or three of its 1700 pressure tubes before the pressure released lifts the lid, introducing air while simultaneously shearing the remaining tubes. Since the heat profile is uneven across the large core even at the beginning of the cycle, and disparities accumulate over time as selective refuelling occurs, there is a potential for localised overheating to cause channel rupture.

The VVER reactors were equipped with partial containment because of the high pressure and temperature inside the compact pressure vessel. Land requirements are less than for RBMKs since VVERs are equipped with secondary cooling circuits and cooling towers rather than huge reservoirs. They are less efficient than RBMKs at producing electricity since losses through the heat exchanger and cooling towers are significant. In addition VVER reactors require frequent refuelling, a process which has been recognised as hazardous by the workers undertaking the task (Z Medvedev 1990:275).

With water acting as both coolant and moderator in a VVER reactor, a loss of coolant accident (LOCA) is less serious than in an RBMK. A hot core can still be subject to meltdown but not to a runaway nuclear reaction in the absence of a moderator. Control of the single large pressure vessel is considerably less complex than for the multi-channel system, and is facilitated by a much greater speed of descent of the control rods. With much less complex piping, there is less scope for mechanical failure of the cooling system, although the relatively weak pressure vessel weld points, subject to unexpectedly rapid

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operational, and 2 at Ignalina (Lithuania).

[10] This had been known to Academicians and officials since 1965 when it was first pointed out by senior nuclear scientist Dr Ivan Zherzhun from the Kurchatov Institute, but his repeated warnings did not pass beyond the atomic bureaucracy and brought only threats of dismissal. (Z Medvedev 1990:59).

embrittlement by neutron irradiation, have given considerable cause for concern.

1.3 Nuclear Bureaucracy and the Soviet Accident Record

Nuclear and other generating capacity, and the associated transmission infrastructure, were under the control of the Ministry of Power and Electrification (Minenergo), although various aspects of nuclear power were assigned to other ministries and departments.[11] In 1985 the Bureau for the Fuel and Energy Complex was given formal jurisdiction over all matters relating to energy, in an apparent attempt to improve integration where necessary for plan fulfilment. Beyond the Bureau, authority ultimately rested with the State Planning Committee (Gosplan), which maintained a staff dedicated to energy matters in its role as the forum where the representatives from the entire energy sector would meet and decisions on political goals and resource allocation would be made.

The operation of nuclear plants during the Soviet era has latterly been documented by those involved at the time as complacent and pointlessly bureaucratic. The most damning account of its shortcomings was scripted by VA Legasov, Deputy Director of the Kurchatov Institute of Atomic Energy and originally a tireless proponent of Soviet nuclear power, and published in *Pravda* (Legasov 1988) shortly after he took his own life on the second anniversary of the Chernobyl accident. The picture painted by Legasov is one of shoddy construction being aggravated by an even worse standard of maintenance, of generally dedicated and attentive personnel frustrated by the presence of others, particularly in management, who were extremely complacent, ill-informed and often unfamiliar with nuclear technology. Qualifications, which were technologically rigorous, and relevant experience were less important than connections in securing a position of responsibility. He recalls decade-long conversations about improving training, none of which ever resulted in action.

Nominal maintenance work was occasionally carried out merely for the sake of fulfilling targets for labour productivity.[12] Reactor experiments were conducted with no thought for the potential

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[11] Control over operations was the responsibility of the All-Union Department for Nuclear Energy (Soyuzatomenergo). Construction was the responsibility of the All-Union Department for the Construction of Nuclear Power Stations (Soyuzatomenergostroy) and the All-Union Central Department for the Construction of Nuclear Power Stations (Soyuztsentratomenergostroy). Management of the nuclear fuel cycle, for both civil and military purposes, was the responsibility of the anonymously named Ministry of Medium Machine Building (Minsredmash). The many nuclear research institutes were unique in their independence from the Academy of Sciences, being instead affiliated to the Ministry of Medium Machine Building or to the State Committee for the Utilisation of Atomic Energy (Gosatom) under AM Petrosyants, which effectively acted as the Ministry's public relations office. The state even had a specific ministry of foreign nuclear power, the All-Union Directorate for Foreign Nuclear Power (Soyuzglavzagranatomenergo). (G Medvedev 1993).

[12] For instance, ensuring that at least a minimum number of seams had been welded whether or not there was evidence of a fault in a specific seam, even if the work might result in the creation of faults rather than their repair.

consequences, with contempt for the point of view of the designer or the scientific supervisor, and with no attention paid to the condition of the instruments or equipment. The attitude of station directors, as communicated to Legasov, was commonly that a reactor was merely a samovar, much simpler than a thermal station, and that nothing could possibly happen (Z Medvedev 1990). The bureaucracy intended to oversee the development and use of nuclear power clearly had either little knowledge of or little power over the actual operation of the technology, and in many cases little interest as long as electricity quotas were met.

It is no longer possible to deny that the leaders of the Soviet Union knew of very significant nuclear accidents (Yaroshinskaya 1995), although it is unlikely that they knew of all due to the incentives for and feasibility of covering up accidents at the level of the plant. The official policy of concealment preventing any adverse impacts from becoming public knowledge was originally enunciated by NS Neprorzhny as Minister of Power and Electrification during the dash for nuclear power, and was continued by his successor AI Maiorets (G Medvedev 1991:20).

It was known to the outside world, because of radioactivity detected abroad, that a very serious incident had occurred in the Urals in 1957. The details which eventually emerged revealed that there had been an explosion in a high-level waste storage tank due to a failure of the cooling system (Z Medvedev 1979). Evidence has also emerged of many other accidents, none of which have yet been officially admitted (Z Medvedev 1990; G Medvedev 1991:17–19; Marples 1986:114). For instance, there is credible evidence of two accidents at the Leningrad plant in successive years in the mid-1970s, the first involving an explosion with fatalities and a significant radioactive release and the second resulting in a partial meltdown and a very much larger release of radioactivity. In successive years in the late 1970s at the Byeloyarsk plant there appear to have been a partial meltdown and a catastrophic oil fire requiring the attendance of 1200 fire-fighters.[13] In 1982 at Chernobyl Unit 1 fuel assemblies were destroyed, resulting in radioactive contamination of the town of Pripyat. Shortly after this fourteen operators were killed at the Balakovo plant when superheated steam entered their workspace due to a valve failure (G Medvedev 1991:18).

Not only were adverse impacts concealed as a matter of policy from the general public and from foreigners, but also from builders and operators of nuclear plants. Thus incidents which could have provided invaluable training information in accident prevention were not only not used in this way but were systematically denied, deliberately fostering a dangerous degree of complacency amongst operators who were repeatedly told that nuclear plants were completely safe (G Medvedev 1991).

[13] Awards for bravery following this accident were later given in secret. (Kamenshchik 1988; Z Medvedev

The only official response to the accidents appears to have been the formation in 1983 of the State Committee for Nuclear Safety (Gospromatomenergonadzor), although a causal relationship has obviously not been admitted. It was headed by YV Kulov, previously Deputy Minister of Medium Machine Building and therefore a civil and military nuclear industry insider (G Medvedev 1991:38). The Committee continued the policy of silence in nuclear matters.

The planning process involved setting annual targets for plant commissioning, but these were not generally met due to the difficulties inherent in the construction process. A common practice throughout Soviet industry, and extending to the nuclear sector, was therefore to sign a project off as complete when in fact much important commissioning work remained to be done. The project would be registered as completed, bonuses would be paid, and an unofficial schedule and division of responsibilities would be agreed for the outstanding requirements. In practice those with responsibility for operations were often left to complete the commissioning phase while running the plant, even if that meant operating nuclear plants before their safety systems had been fully installed or tested (Z Medvedev 1990:12–19).

Once operational, plants would be given targets for electricity production, with rewards for meeting them at whatever potential cost in terms of increased risk. It was not uncommon for plant maintenance time to be curtailed across the board in order to meet targets, sometimes by direct edict from the Minister of Power and Electrification, with no regard to the degree of urgency of the repair programme at different installations. Nor were plants automatically taken out of service when their safety systems were off line for maintenance, despite the obvious risk of operating under such circumstances. Ministers who used their power to force plants to decrease downtime were in fact rewarded. Minister Maiorets, holder of the post in the mid 1980s, was lauded by Politburo for doing exactly this three months before the accident at Chernobyl (G Medvedev 1991).

Chernobyl Unit 4 was signed on as operational by its director at the end of 1983, in order to qualify for bonuses, despite the fact that it was not yet fully tested. The safety features were not fully compliant with design requirements, specifically the reactor was unacceptably vulnerable to station blackout, but it was commissioned in any case (Z Medvedev 1990:13). After two years of operation during which a loss of electrical power could have precipitated disaster at any time, a test programme was designed for a newly installed device intended to remedy the previous deficiency, but the proposals were seriously flawed. The dangerous aspects of mimicking a blackout for test purposes were not, however, detected by the State Committee for Nuclear Safety (G Medvedev 1991:38).

1990:278).

The operators were unprepared and relatively inexperienced, and were bullied into carrying out the test despite their protests that the reactor was in an unstable state at the time. Errors were made in the attempt to stabilise the reactor, reducing the ability of the operators to control the core. Acting synergistically with the design flaws of the reactor, this triggered a prompt neutron surge leading to a series of explosions. The graphite moderator ignited and attempts to extinguish the fire caused water to accumulate in the cable channels beneath the reactor, very nearly causing a loss of power to the other three connected units on site. Very high levels of radiation continued to be emitted for a further ten days until the graphite fire burned itself out. Estimates vary but it appears that some fifty million Curies of radiation was emitted.

The response was a defensive consolidation of the nuclear industry under a new Ministry of Atomic Power (Minatom) between 1986 and 1989. Modifications were hastily made to the remaining RBMK reactors, notably the reduction of the positive void coefficient by insertion of additional fixed control rods, and the output of the larger models was scaled down in order to reduce the inherent instability within the core. Operational edicts were belatedly issued, for instance regarding the number of moveable control rods which must remain in the core under all circumstances, and new rules concerning the minimum distance between plants and centres of population were decreed so that most planned nuclear district heating schemes were effectively cancelled.[14] The State Committee for Nuclear Safety, Gospromatomenergonadzor, was reformed in 1989 as Gosatomenergonadzor (GAEN), but remained legally dependent on Minatom for approval of its proposed regulations (Afanasiev 1996). Therefore the nuclear industry remained essentially a law unto itself with no legal basis for control of the secretive bureaucracy, and no entity charged with defending the public interest.

The most significant change was the public perception of nuclear power (Marples 1991; Dawson 1996). Ironically the paucity of accurate information available to the public exacerbated the public response since it allowed rumours about the disaster and its cover-up to proliferate, fostering a reflexive disbelief of official assurances regarding the safety of other installations (Yaroshinskaya 1995). Thus local opposition eventually forced the cancellation of most nuclear projects, even if they had been nearing completion. The dash for nuclear power was brought effectively to a standstill by the late 1980s.

1.4 Summary

- The adherence of the central planning system to a narrowly-based supply-side strategy resulted in

[14] Nuclear heating plants at Bilibino in the far eastern arctic and in the erstwhile closed nuclear cities of Tomsk-7 and Kransnoyarsk-26 have remained operational.

a self-inflicted energy crisis.

- The conflicting priorities of exports for hard currency and subsidised exports fostering eastern consolidation were to be resolved through the development of nuclear power in Central Europe and the Soviet Union.
- The emphasis on achieving construction targets, and the perverse incentive structure which this engendered, resulted in construction in a manner and at a pace incompatible with attention to quality. Production targets similarly obstructed safe operation.
- Control of the nuclear industry by the state, though the purpose of an extensive bureaucracy, was effectively impossible under the prevailing conditions of misinformation.
- Concealment of operating experience and previous accidents from nuclear operators and from the public created an atmosphere of complacency and prevented learning from past errors.
- The accident at Chernobyl failed to improve nuclear governance, although its substantial effect on public opinion resulted in the cancellation of the existing nuclear programme.

2. THE FRAGMENTATION OF THE EASTERN BLOC AND ITS EFFECTS ON THE NUCLEAR SECTOR

2.1 Effects of Political Independence on the Economics of Energy

The Soviet Union began to lose its client states in 1989, and the subsequent disintegration into its component parts of the USSR itself in 1991 completed the collapse of the empire. The CMEA ceased to exist, and the formation of the Commonwealth of Independent States (CIS) could not transcend the determination of the erstwhile Soviet Republics to pursue independent nationalist agendas. The Russian Federation could not, as the Soviet Union had done, lead a united Bloc held together by economic and military means. Its political influence sharply reduced, and experiencing severe economic contraction, it saw no need to assume the old Soviet responsibility for Central and Eastern European industrial development, the most important component of which had been plentiful exports of cheap energy.

Indeed, even if Russia had still wished to continue large-scale energy subsidies to Eastern Europe and the newly independent states it would not have been able to do so. Oil production had begun a sharp decline in 1989[15] which accelerated in the 1990s as the post-communist economic collapse deepened. With oil revenues slashed by the combination of reduced production and lower prices on foreign markets, there was an acute need for hard currency. Energy exports to the former Eastern Bloc were therefore provided at ever-increasing prices. The economic crisis in these states was significantly worsened by the sudden need to pay high prices for energy, particularly since the inefficiency with which cheap energy had been used could not be quickly remedied. Industrial production in many states went into free-fall and both heat and electricity supplied for domestic use were frequently curtailed. The common response amongst the Eastern nuclear states was to make maximum use of their non-fossil fuel generating capacity in order to reduce both their potential indebtedness and the degree of their dependency on Russia (Ebel 1997).

2.2 Economic Effects of the Transition from Central Planning to the Market

The Soviet central planning system has been described as an elaborate network of subsidies for the generation of negative added value, ultimately supported by the sale of natural resources abroad (Gaddy and Ickes 1998). Revenues were collected centrally and funds then distributed through the hierarchy for the fulfilment of obligations at all levels under the plan. With production mandated by the state and producers paid by the state at an arbitrary price, there was no need to rely on the collection of payments from consumers. The collapse of the centralised system greatly reduced central disbursements, leaving

[15] Rosneftegastroy statistics.

regions and industry to raise much of their necessary revenue through their own activities. The relationship between producers, consumers and local government was abruptly left to function in a vacuum, devoid of the legal and institutional context necessary to function on a large scale.

The effect of transition on the nuclear industry in the Soviet successor states, particularly Russia and the Ukraine where heavy industry was concentrated, has been profound. Where once wage bills and social benefits for power station workers would have been met from central funds, they were suddenly expected to be covered by income accruing to the plant from the sale of electricity. This revenue stream was, however, dependent on electricity consumers paying their bills, which they have almost universally failed to do.[16]

Cost recovery from domestic consumers is generally impossible due to the disparity between the average household income and energy bills at market prices, especially with the spectre of unemployment looming large. Industry is generally aware that payment is unenforceable. Local government is expected to maintain substantial energy subsidies to households, which it does in preference to settling its own utility bills (Martinot 1997). The right of plant managers to cut off supplies to errant consumers remains rare, hence plants must generally continue to supply whether or not they are paid for their product. Without access to credit markets to provide finance and with no means of securing revenue, wages remain unpaid and plant maintenance is continually postponed. Throughout the economy the network of subsidies has become an intractable web of debt (Gaddy and Ickes 1998), which the current economic crisis is set to exacerbate significantly.

Similar problems have beset the Eastern European recipients of Soviet nuclear technology, but not all in equal measure. Hungary and the Czech Republic have avoided the worst of the aftermath of central planning (Bateman 1997). Slovakia has suffered to a greater extent and Bulgaria has done particularly badly.[17] The nuclear plants in the latter countries have unsurprisingly faced more severe economic conditions than those in the former.

2.3 Social Stresses as a Result of Restructuring

The social responsibilities of Soviet industry were far more extensive than the mere payment of wages to directly employed individuals. Civil society, that is the social element of life independent of the party and hence of the state, was minimal, while reliance on the state and its industrial organs was encouraged.

[16] The energy sector in the Ukraine was owed an estimated $2.5 billion as of April 1998. *Energy Economist* (1998) 198:32.
[17] OECD (1997). OECD Economic Surveys: Bulgaria 1997.

Under central planning a town would often have been built to serve a specific plant,[18] and the managers, as servants of the state, assumed responsibility for its inhabitants. Housing, schools, hospitals, services and amenities were provided and maintained.

Under the transitional system some post-Soviet industries have been able to shed these responsibilities, generally passing them on to less-than-willing local authorities, but others have had no option but to continue to service them (Martinot 1997). Russian nuclear power plants have often been in the latter category, especially where there is no other employer in a purpose-built town, but the means to pay for such out-goings has evaporated. Social spending priorities therefore compete with wages and plant maintenance, often ending in default on all grounds. Employees may not be paid for months at a time. Groups periodically march on Moscow to demand payment of wage arrears, whereupon the central government may meet the settlement temporarily, but arrears begin to accumulate again almost immediately. Plants in inhospitable regions, such as Kola in the Russian arctic where employees used to be paid a premium for enduring the bleak conditions, have experienced a considerable loss of qualified staff. Many employees have emigrated to take advantage of higher salaries and better conditions in other countries with nuclear programmes.

Nuclear plants in the other post-Soviet states have also suffered from problems of debt and loss of qualified personnel, the latter being even more serious than in Russia. Many of the experienced operators were Russians who did not wish to live as part of a potentially persecuted minority in what was now a foreign country. Resident ethnic Russians were not always granted citizenship in the newly independent states, sometimes being forced to pass a language test or other humiliating requirement. Economic conditions were almost universally worse than in Russia, notably in the Ukraine where the new currency declined rapidly against the rouble.

Social stresses in the former client states of Central Europe have been dependent on the severity of the economic transition and on the strength of the indigenous civil society, both of which have varied considerably. The effect on the nuclear industry appears to have been least in Hungary and greatest in Bulgaria, where the country teetered on the verge of bankruptcy in 1997.

2.4 The Weakening of Legitimate Political Authority

The transition from central control of policy and funding to *de facto* political and financial devolution was not simply a voluntary shedding of burdensome responsibility by the central authorities. In fact

[18] For instance, in the nuclear sector, Enerhodar was built to serve the Zaporizhia plant and Pripyat to serve Chernobyl.

central control over the implementation of economic policy had been steadily eroding for years as the lack of accurate information available to the Politburo had led to a progressively cruder picture of reality from which it had become increasingly difficult to make meaningful choices (Gustafson 1989). In addition, an extensive network of informal connections for the exchange of money and favours had developed (Bartlett 1997, Ledeneva 1998), the effect of which was often to undermine further the formal agenda as described in the plan.

The over-extended system eventually could no longer maintain central control, and in the post-communist era the vacuum was filled by a *menage* of the old *nomenklatura*, regional and local authorities, industrial concerns, audaciously successful new entrepreneurs and well-connected beneficiaries of the old grey economy. The elected central government which subsequently replaced the statutory rule of the communist party could not have exerted the control associated with the *ancien regime* even if it had wished to do so. The result appears to be an increasingly tenuous grasp on policy and its implementation at the centre while power accrues to the informal and unaccountable alliances between the new capitalists, the old and new bureaucrats and, frequently, organised crime (Tsepkalo 1998; Jensen 1998; Batakovic 1995).

The other post-Soviet states and the nuclear states of Eastern Europe have suffered a similar crisis of governance, with legitimate central authority eroded by the active grey economy, but not generally to the same extent as the Russian Federation. The scale of the nuclear industry and of the countries themselves is of a different order of magnitude in a situation where both these factors impinge significantly on the ability to retain control. The Baltics, the Balkans and the Ukraine have experienced the most difficulties in this regard.

2.5 Nuclear Bureaucracy in Transition

Minatom, as a Russian bastion of strategic importance, has been partially insulated from both restructuring under *perestroika* and from the effects of transition and has therefore retained much of the cohesiveness of a closed bureaucracy. Its remit was restructured by Presidential decree in January 1992 (Afanasiev 1996:7), and broadened to include ensuring the safety of nuclear facilities and providing ecological rehabilitation of contaminated sites. The decree also instructed Minatom to move towards conversion of the military-industrial complex into commercial enterprises, hence Minatom has created several joint-stock companies in which it retains a 51 per cent share. The Rosenergoatom consortium formed under this initiative is now responsible for the operation of all civilian nuclear power plants, with the exception of the Leningrad facility.

The Soviet-era regulatory body, GAEN, was renamed Gosatomnadzor (GAN) and its status elevated by decree in December 1991, rendering it answerable directly to the presidential administration rather than to the ministry it was intended to regulate (Afanasiev 1996:10). Although nominally independent from this time, it has suffered to a much greater extent from the budgetary crisis than Minatom appears to have done, and has been considerably hampered as a result. GAN has had limited regulatory power over Minatom from its inception,[19] but the balance of power has tilted in favour of Minatom during the economic and political turmoil of the transition period. A significant percentage of on-site inspection posts remain vacant due to lack of funds, and existing inspectors may only be nominally independent of plant management.[20] There has been no legal requirement for the plants to follow the recommendations of inspectors in any case (General Audit Office 1995).

The Moscow-based nuclear institutions directly controlled the industry throughout the Soviet Union and indirectly controlled it, to at least some extent, in the former client states. These institutions, with a near-monopoly on Eastern Bloc nuclear expertise, now serve only Russia. Independence for the other nuclear states has therefore involved creating and staffing institutions largely from scratch, in addition to having to run plants with fewer qualified or experienced staff. The difficulty of this task has been exacerbated by the acute shortage of resources. Most have modelled their new institutional arrangements along Western lines, with independent regulatory bodies and mechanisms for licensing and inspections of nuclear plants.[21]

2.6 National Pride and a Nuclear Future

In the former communist countries, and especially in the Soviet Union itself, technological progress was an article of faith, indispensable to the grand utopian vision.[22] Advanced technology was thus a matter of national pride, inextricably linked with superpower status. Chernobyl had the effect of undermining this perception for a decade, but the demeaning experience of economic transition coupled with thinly veiled Western contempt for Soviet achievements is breeding resentment against Western interference and a renewed resolve to pursue indigenous technological development.

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[19] GAN has a staff of 2000 spread across its Moscow headquarters (200), the Science and Technical Center (300) and the regional offices in St Petersburg, Balakovo, Ekaterinburg, Khabarovsk, Novovoronezh and Novosibirsk (1500). Minatom, in contrast, employs 1million people (2% of the Russian workforce). GAN has no power to regulate Minatom's policies or public disclosures and there is no mechanism for calling to account plant managers in violation of safety standards. (Allison 1996; Afanasiev 1996)

[20] See for instance reference to Order No 112 (23.07.92) 'On monthly additional salary payments to the officials of Gosatomnadzor' (http://www.ngo.grida.no/ngo/naturvern/russland/news-1.htm).

[21] See national contributions to IAEA/NEA/EC legal seminars. Regional Information Seminar on Nuclear Law for CIS, Almaty, Kazakhstan 26-28 May 1997, The Convergence of Legislation in Central and Eastern Europe with EU and International Nuclear Law, Dubrovnik, Croatia 25-29 August 1997.

Central planning and technological determinism both involved the search for certainty and predictability, in contrast to the perceived dangerous uncontrollability of markets and democracy, hence the continued emphasis on supposedly straightforward technological solutions. There is no general faith in the market as a mechanism for providing solutions to concerns such as security of energy supply, in fact markets have come to be associated for many people with the chaos, visible injustice and societal breakdown of the transition period. The desire for a return to the certainty of the old regime is palpable amongst large segments of the population, particularly the employees of the nuclear sector who had once benefited from privileged status as a symbol of communist modernity (Popova 1993).

Minatom is determined to retain as much power and influence as possible by expanding and modernising the domestic nuclear sector. It also markets its technology aggressively abroad in order to generate the income which remains unavailable through its operations in Russia.[23] In this way it hopes to survive the transition period largely intact, unlike most other aspects of Soviet bureaucracy. Minatom is generally treated by the West as an unreconstructed bastion of the old Soviet state devoid of reformist elements and therefore unworthy of respectful treatment despite the technical competence of many staff. Such an attitude, which underestimates the power and pride of Minatom, is unlikely to foster the atmosphere of co-operation necessary if the West is to have any influence over nuclear events in Russia.

The other states of Eastern Europe and the former Soviet Union have also felt patronised by the West, which seems to treat their countries as junior partners at best, or worse, as basket cases. These states do not wish to be dependent on Russia, but nor do they wish to be subject to the rigours of Western energy markets. Nationalist sentiment is therefore flourishing, along with a desire to demonstrate both independence and modernity where possible through the development of indigenous energy resources. Nuclear development is seen as the ideal means to achieve both energy security and increased status.

2.7 Summary

- The Russian Federation no longer plays the former Soviet role of guarantor of affordable energy supplies to the other post-Soviet or former client states. These countries now have to pay near-market prices for their energy and have consequently accumulated large energy debts. Where they have the choice, they have opted to maximise their use of nuclear infrastructure as an alternative to importing Russian hydrocarbons.
- Chains of debt have accumulated within the states of the former Eastern Bloc due to non-payment

[22] Indeed Lenin himself decreed in the 1920s that communism was the sum of socialism and electrification.
[23] Minatom is hoping to increase its export income to $3.5 billion by 2000, partially through contracts with Iran, India and Cuba.

to energy producers. Nuclear plants therefore have insufficient revenue to pay wages and undertake maintenance and repairs.

- Social infrastructure, once the responsibility of the local plant, can no longer be funded. This aggravates the growing shortage of skilled and experienced personnel, especially outside Russia.
- Legitimate central authority has been seriously eroded during the transition period, leading to a crisis of governance which makes economic and political problems more difficult to address in the public interest.
- Minatom has retained much of its cohesiveness due to its privileged position, which partially protected it from restructuring. GAN has suffered to a much greater extent, particularly from lack of funding, hence regulation is inadequate.
- Nuclear technology is often a matter of national pride, not only in Russia where it is still associated with superpower status but also in other newly nationalistic independent states. The bureaucracy which controlled nuclear power in the Soviet era, virtually all of which is centred in Moscow, remains a force to be reckoned with and is committed to a nuclear future in the East.

3. THE INTERVENTION OF THE INTERNATIONAL COMMUNITY

3.1 The Initial International Reaction

Prior to the accident at Chernobyl there had been little international concern over the nuclear programme in the Soviet sphere since Russian technological prowess was well known and respected, even feared. The cumulative effect on the nuclear industry of years of mismanagement was not yet obvious. Following Chernobyl the Soviet Union sent Valery Legasov, Deputy Director of the Kurchatov Nuclear Research Institute, to Vienna to offer an explanation for the accident, although by Legasov's own later admission it was not the whole truth. By blaming the operators at Chernobyl of gross violations of operating procedures the explanation sought to exonerate the technological and institutional aspects and to allay fears that such an accident could ever occur again. The Soviet Union was praised for its candour at the time and concern was partially assuaged, until the opening of Eastern Europe and the FSU permitted meaningful international scrutiny of Eastern nuclear facilities for the first time.

The 1990 inspection of Kozloduy in Bulgaria horrified the Western nuclear industry and its regulators, generating political pressure for action at a time of high environmental awareness. Inspections by the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO) suggested that Chernobyl might not remain an isolated incident if technological, managerial, institutional and socio-economic issues were not addressed as a matter of urgency. Nuclear safety, which had traditionally been perceived as a national matter, was suddenly perceived as requiring a much more significant international dimension.

3.2 The General Conference on Nuclear Safety and the Lisbon Initiative

The 1991 General Conference on Nuclear Safety, under the auspices of the IAEA, was intended to set a co-operative international agenda for the future use of nuclear power, in recognition of the predictable effect of another accident on the outcome of the battle for public acceptability. The Conference sought to establish international agreement as to the fundamental principles for safe reactor operation. The participants wished to devise a standard approach for assessing the current safety of plants built to earlier standards in order to identify and prioritise both opportunities for upgrading, which would then be undertaken with the assistance of the international community, and targets for early closure. Socio-economic factors were to be taken into consideration in the decision to close a reactor, but were not to be the deciding factor. In particular, the participants expressed an opinion that obsolete plants for which upgrades identified as a necessary minimum would not be economic should be closed as soon as possible and the generating capacity replaced through international investment (IAEA GC(XXXV)/970 1991).

Nuclear safety was to remain formally a national responsibility, but with greater recourse to the existing international framework for the setting of standards, dissemination of information and provision of voluntary oversight. The work and the necessary funding for required improvements was to be undertaken primarily by a variety of new and existing international bodies, but also on a bilateral basis between donor and recipient countries.

At the May 1992 Lisbon meeting of the G-7, a co-operative Multilateral Nuclear Safety Initiative was proposed, since referred to as the Lisbon Initiative, which was intended to achieve a balance between closure of the least safe plants, safety up-grading of the remainder, the provision of alternative generating capacity and the restructuring of the energy sector. It was formally presented at the July meeting in Munich and agreed by October 1992. The G-7 initially sought agreement on the closure of all RBMK plants by the year 2000 and also on the phasing out of the first generation VVER 440/230 plants. For this reason, only short-term investments to address obvious and immediate safety risks were to be made for these reactors. Second generation VVER 440/213 models were secondary targets for the closure lobby, while the third generation VVER 1000 model appeared to meet the criteria for long-term viability. A process of in-depth design review was initiated in order to confirm these initial perceptions.

3.3 The Developing Roles of the Established International Actors

International nuclear agencies originated with the spread of civilian nuclear power generation technology in the 1950s. The primary aim was to prevent a potential proliferation of nuclear weapons rather than to control aspects of the operation of purely civilian facilities. Some aspects of health and environmental protection were considered important enough to include in the regime, but they were treated as minor provisions at the time. States were encouraged and assisted to develop nuclear power generation in exchange for providing an undertaking not to build weapons, a deal referred to as 'atoms for peace' (Braithwaite unpublished). The potential conflict of interest between promotion and regulation mirrors that built into the national nuclear commissions of the time, but appears to have been less controversial in the international sphere where there are generally no legally binding regulatory powers.[24]

The IAEA was founded in 1957 as the main United Nations body to oversee nuclear development under a voluntary regime of military nuclear safeguards, and was under heavy American influence from its inception (Braithwaite unpublished). Its Statute instructs the IAEA to 'establish or adopt standards of safety for protection of health and minimisation of danger to life and property', a function which, while

[24] For instance, in keeping with the provision of the IAEA Statute that its activities are to be undertaken 'with due observance of the sovereign rights of states', the Agency can exercise its functions within states only by

initially an afterthought, has subsequently allowed the Agency to develop a considerable body of safety norms and to assist in their implementation when requested to do so by Member States. The Nuclear Safety Standards (NUSS) programme was established in 1974 with the goal of preparing Codes of Practice and Safety Guides in the fields of government organisation, siting, design, operations and quality assurance. Although compliance with IAEA standards cannot be directly enforced in the absence of an official regulatory role, the extensive consultation process involved in their development appears to have resulted in a widely respected and therefore widely adopted body of technical guidance based on current best practice in the industry.

EURATOM, the basis of the consolidated development of a European nuclear industry, was also founded in 1957. Like the IAEA, it was established to promote the development of a nuclear common market while simultaneously accounting for production of fissile materials through non-proliferation safeguards. Aspects such as health and safety (Articles 30–39) are also the subjects of basic standards.[25] Unlike the IAEA, EURATOM does have legislative authority within its jurisdiction and has the right to send inspectors into Member States (Article 161).

The Nuclear Energy Agency (NEA) at the OECD was formed in 1958.[26] The participating countries, including the Czech Republic and Hungary as of 1996, represent 85 per cent of the world installed nuclear capacity. The NEA also has the dual roles of promoting research and joint undertakings in the nuclear sector (Articles 5 and 7) and developing safety regulations for the protection of workers, the public and the environment (Article 8).

These existing bodies have expanded their roles considerably since the collapse of the Soviet Union revealed the extent of the problems with nuclear safety in the East. All have become conduits for the transfer of technology, expertise, and, to different extents, funding. The IAEA has been heavily involved in promoting its technical standards, undertaking voluntary assessments and assisting with the implementation of technical upgrades. EURATOM is empowered, as of 1994, to issue loans for contributing to the financing of safety and efficiency improvements at nuclear power stations outside the European Union, where a major share of the financing is provided by a European Union enterprise. The European Commission, which acts through EURATOM, also administers major new funding

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invitation and only to the extent agreed with the state.

[25] Directives laying down the basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation, first issued in 1959, latest version 1996.

[26] Its purpose, as defined in its Statute, as amended in 1995, is 'to further the development of the production and uses of nuclear energy…for peaceful purposes by the participating countries, through co-operation between those countries and a harmonisation of measures taken at the national level', while 'taking due account of the public interest and mindful of the need to prevent proliferation'.

programmes including PHARE, for the development of Eastern European states,[27] and TACIS (Technical Assistance to the Commonwealth of Independent States). The NEA works with the OECD Centre for Co-operation with Economies in Transition (CCET) to assist Central European and FSU countries with nuclear safety research programmes, particularly for VVER reactors. Its Committee on Nuclear Regulatory Activities (CNRA) has established a link with the Association of Regulatory Bodies of Countries Operating VVER Reactors in order to enhance the credibility and authority of the new regulators.

The power and influence of EURATOM are likely to increase substantially in the future through the process of negotiated accession of former Eastern Bloc states to the European Union. Accession would not be permitted where perceived nuclear safety problems exist due to the agreement between members to share responsibility for the consequences of an accident. States wishing to join the European Union would benefit from this provision and would therefore be expected to have reached agreed standards of safety prior to accession. The process will act as an effective conduit for political pressure due to the almost universal desire to join amongst Central and Eastern European states. Once new members have joined they will be subject to the same mandatory control regime as the existing membership.

With the degree of influence exerted by the existing international nuclear agencies having increased dramatically in recent years, there is greater concern, particularly amongst the public in Central and Eastern Europe, regarding the potential conflict of interest inherent in their dual promotional and regulatory roles. Among the established agencies there is no international equivalent of the independent regulator charged with safeguarding the public interest, a key requirement of all modern Western national regulatory regimes. There is also no mechanism for public participation in either the standard setting or compliance monitoring procedures. Sensitive information is held privately by those with an interest in a viable future for the industry, and it is left to their discretion to decide what should be made publicly available.

3.4 New International Bodies

In addition to the traditional international nuclear agencies, several other bodies have been created to address the general problems of Eastern transition and specific concerns over nuclear safety. The European Bank for Reconstruction and Development (EBRD) was formed to finance the redevelopment of Eastern Europe and the FSU, and has become increasingly involved in the financing of nuclear safety upgrades. A programme specifically formulated to channel nuclear safety investments, the Nuclear

[27] PHARE was established in 1989 to assist Poland and Hungary and was extended to Bulgaria, Czechoslovakia, Romania and Yugoslavia in 1990.

Safety Account (NSA), was established in 1993. Funds are pledged by EBRD members and others in order to mitigate the immediate safety concerns at the highest risk reactors.[28]

The G-24[29] Working Group on Nuclear Safety was established in 1991. The Nuclear Safety Assistance Co-ordination Centre, its Brussels-based secretariat, collects and distributes information on safety initiatives being undertaken by the different parties. A ten-country executive steering committee was established in 1992 to bring together donors and recipients of aid. The Centre is assuming an increasingly important co-ordinating role for the nuclear safety programme, having compiled, with the IAEA, a database of 850 safety projects by 1996. The database is used to identify and remedy duplication or omissions in the overall programme.

Potentially the most significant new organisation is the World Association of Nuclear Operators (WANO), modelled on the Institute for Nuclear Power Operations (INPO) in America. As an exercise in self-regulation INPO has been much more effective than one would expect,[30] largely as a result of the perception within the industry that its collective future depends on the prevention of further accidents (Rees 1994). WANO was formed in 1989 and currently has universal subscription world-wide amongst utilities operating nuclear plants. Its mission is 'to maximise the safety and reliability of the operation of nuclear power plants by exchanging information and by encouraging communication, comparison and emulation amongst its members'. By early 1991 teams from every nuclear plant in the former Eastern Bloc had visited Western plants to exchange information between operators, and there has since been an on-going programme of voluntary peer review visits by small teams of experienced operators to Eastern plants.

Like the traditional nuclear agencies, the new bodies are staffed by nuclear professionals and have taken a generally pro-nuclear stance. They vary in their willingness to make their opinions and assessment information public and some may therefore exercise an influential role behind closed doors. The new institutions therefore perpetuate the duality of promotional and quasi-regulatory roles at the international level despite the rejection of this model of governance nationally.

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[28] The financing procedures of the EBRD require that proposed projects be subject to due diligence, including analysis of economic and environmental factors with appropriate public participation. Energy projects must also satisfy conditions for lending as defined in the EBRD Energy Operations Policy, a major requirement of which is compliance with the criterion of least cost.

[29] The G-24 is comprised of the membership of the OECD and Turkey.

[30] In fact it has been recognised even by high profile nuclear sceptics that INPO has been much more effective in identifying and tackling problems than has the Nuclear Regulatory Commission (NRC), which has in some spheres devolved its role to INPO. (Rees 1994).

3.5 Modes of Intervention

Despite the large volume of safety guidance provided by the IAEA and others, and the discussions taking place in various international fora, it is problematic to suggest that there was an international consensus on nuclear safety in 1991, or in fact to propose that one has developed since. The obvious difficulties facing the former Eastern Bloc have resulted in a significant challenge to the received wisdom of the traditional Western approach to safety, interacting with a critique which was already developing in response to Chernobyl. The 1990s have thus been witness to a period of both frantic activity and intense reflection on the nature of safety and the means for securing it, especially when one cannot rely on the existence of the relatively uniform social and economic context as has generally been presumed in the Western nuclear risk discourse.

It is therefore necessary to assess the various modes of intervention and the assumptions as to the nature of safety upon which they rest. Broadly speaking, one can refer to technological, human and regulatory programmes, where the latter can be divided into binding national and advisory international initiatives. All are being undertaken simultaneously, but unevenly, against a backdrop of economic transition which itself varies both spatially and temporally. It is therefore too soon to draw firm conclusions as to the merits of each approach, but patterns are beginning to emerge which may guide the distribution of scarce resources and may also change the way that safety is viewed throughout the nuclear industry. Each approach will be reviewed in turn in the following chapters, concluding with an overview of the political debate surrounding the future of facilities currently the subject of profound disagreements between East and West.

3.6 Summary

- The initial international reaction to the state of the nuclear industry in Central and Eastern Europe and the FSU was one of extreme concern. The General Conference on Nuclear Safety of 1991 and the Lisbon Initiative of 1992 were expressions of this concern.
- It was agreed in both instances that the oldest and most dangerous reactors should be phased out by the year 2000, while the newest models would be upgraded to meet international safety standards. Western assistance was also promised with the provision of new generating capacity and the restructuring of the energy sector.
- The roles of the existing international nuclear agencies, the IAEA, EURATOM and the NEA, have been expanded considerably in order to address the problem. They have greater influence than ever before and act as channels for significant levels of funding, but retain the outdated dual roles of promotion and control which characterised the early national nuclear regulators.

- Additional international nuclear bodies have been formed, namely the NSA, the G-24 Co-ordination Secretariat and WANO. With the possible exception of the G-24, these also have a vested interest in the future of the nuclear industry. WANO is of particular interest given the success of its national predecessor INPO in the USA.
- Various modes of intervention have been undertaken, the merits of which will be considered in turn.

4. FOCUS ON THE TECHNOLOGICAL ASPECTS AT NUCLEAR FACILITIES

4.1 The Traditional Approach

The development of stringent nuclear safety regulation can be interpreted partly as a response by Western governments to a loss of public faith in the institutional arrangements for the governance of nuclear power and consequent public pressure to increase control over the industry. The process was, unsurprisingly, given additional impetus by the 1979 accident at TMI in America, where what was probably a gross failure of effective communication was seen by many as a cover up (Rubin 1982). The Soviet Union, in contrast, failed to develop a functional system of safety controls due to the overriding priority explicitly accorded to production targets and the lack of available information on the safety record even within the industry itself (G Medvedev 1991). Propaganda as to a glorious nuclear future (Kazachkovsky 1984) helped to stifle public debate, ensuring that public pressure did not become an issue until Chernobyl, by which time the international nuclear institutions had been built on a Western model.[31]

The approach initially taken by Western regulators was an engineering one, largely applied at the design stage. Nuclear regulators, themselves generally engineers by training, were generally most comfortable with technologically based assessments of design or operational problems, and often with regulation in accordance with prescriptive, and ever more comprehensive, engineering standards as a consequence. The cumulative effect of this technologically deterministic approach is the concept of defence-in-depth, whereby the system is constructed with a high degree of redundancy and with layers of back-up measures capable of compensating for the potential failure of any given safety response. For instance, a reactor might be required to have two or even three systems for automatic shut-down, each of which is spatially and conceptually independent in order to avoid common mode failures. It would also have a containment system theoretically capable of preventing the release of radioactivity to the environment in the event of a design-basis accident.[32]

Regulation was originally proactive only at the design stage, where purely mechanical and electrical systems could be modelled relatively easily. Theoretical weak points could be identified and then compensated for through additional engineering requirements. Operational problems were addressed

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[31] Nuclear Safety is defined as 'the achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in the protection of site personnel, the public and the environment from undue radiation hazards'. IAEA Code on Safety of Nuclear Power Plants - Operations.
[32] A design-basis accident would be the most serious potential accident of which the designers or regulators could conceive. The reactor plans would be approved only once the designers could convincingly demonstrate

reactively through retrofitting alterations to existing plants where possible and by tightening the design requirements for subsequent plants. Minimum standards for addressing potential weak points, identified theoretically or in practice, collectively formed the basis for traditional Western nuclear regulation at the national level, and have been the foundation for voluntary safety standards of the original Western-dominated international nuclear agencies such as the IAEA.

4.2 Technical Guidance at the International Level

The IAEA has developed a considerable body of technical guidance under the NUSS (Nuclear Safety Series) programme initiated in 1974. While not as detailed and prescriptive as the standards applied, for instance, in the USA by the Nuclear Regulatory Commission (Braithwaite unpublished) they do share a predominantly technological focus. Guidance on human aspects has become increasingly apparent from the late 1980s onwards, but consideration of management issues remained underdeveloped. The NUSS programme consists of five general Codes of Practice, each of which is accompanied by a series of safety guides suggesting means of implementation.[33] Most of the guides date from the mid-1980s and therefore do not necessarily reflect current Western national practice, which has evolved considerably in the decade since the Chernobyl accident. Virtually all, even many of those updated under the on-going revision process, predate the disintegration of the Soviet Union and the safety experience gained since in the process of mitigating very serious safety concerns.

In 1996 the IAEA decided to replace the NUSS with a new Safety Standards Series, comprised of Safety Fundamentals expressing objectives and principles, Safety Requirements intended to serve as a basis for national regulatory systems and supplementary Safety Guides (IAEA STI/PUB/1034 1997). The new guidance material is intended to consolidate the extensive technical expertise, taking into account the experience gained in the former Eastern Bloc, while developing the operational, managerial and institutional aspects. It is clear that the international standards regime administered by the IAEA is itself in a state of transition, but that the effect of these changes in emphasis may take some time to be fully developed and applied.

4.3 Design Safety Reviews and the International Prioritisation of Safety Issues

The IAEA initiated a generic safety analysis programme for the VVER 440/230 plant design in 1990, which was expanded in 1992 to encompass VVER 440/213, VVER 1000 and RBMK reactors. By 1994 long lists of safety deficiencies, as measured against international standards such as the NUSS guidance,

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to the regulators that the design would theoretically be capable of containing the consequences of that accident.

[33] The Codes relate to governmental organisation, siting, plant design, plant operation and quality assurance.

were compiled (IAEA-TECDOC 773/1994), causing a considerable degree of concern and leading to calls for safety expenditure on a vast scale. Since it was clear that most of the earlier plants, and all the RBMKs, could not be upgraded to meet the IAEA standards, the completion of the programme strengthened calls for the closure of these reactors.

The RBMK programme recognised three generations of RBMK reactor, of which the earliest design causes the most concern.[34] Despite modifications made by the Soviet authorities after Chernobyl, all RBMK reactors still show a reduced but unavoidable positive void coefficient. The shutdown system, although improved in terms of speed and effectiveness by the Soviets, remains inadequate in light of this potential for rapid power surges. RBMKs also remain inherently unstable and difficult to control, especially at low power.[35] The absence of containment is therefore a matter of the utmost concern. In all 58 safety issues were identified.

For the VVER 440/230 model, the integrity of the reactor pressure vessel and the primary circuit pipes are of major concern in the light of the limited capacity of the emergency core cooling system and the lack of containment. In addition, the safety and support systems were found to be inadequate to maintain control during abnormal operating conditions. Measures to address the seismic risk to specific plants were often judged to be inadequate. The IAEA specified 97 safety issues for the VVER 440/230.

The IAEA safety analysis confirmed that both the RBMK and VVER 440/230 designs could not be upgraded to meet international standards, the former for reasons inherent in the design and the latter because the degree of retrofitting which would be required would be unjustifiable on economic grounds. On this basis it was judged that only the most urgent short-term safety improvements should be made, in order to reduce the immediate risk, but that further expenditure could not be justified. Funding for short-term safety improvements was generally made conditional on an agreement with the state concerned that the plant would be closed after a transitional period during which alternative electricity supply arrangements would be made. These transitional periods are now beginning to expire, but persistent economic difficulties have prevented the development of alternatives, hence states are choosing to retain their ageing nuclear capacity despite the agreements.[36] Failure to adhere to the

[34] The first generation of RBMK reactors lacks dedicated emergency core cooling and pressure suppression systems.
[35] The reactor exhibits a tendency to low-flow transients in multiple parallel channels which renders it vulnerable to multiple pressure tube failure. The consequence of such an occurrence affecting three or more pressure tubes simultaneously would likely be the catastrophic destruction of the core through the release of steam pressure, as was the case at Chernobyl.
[36] For instance, 24 million ecu of EBRD funding for Kozlodui in 1993 was conditional on the shutdown of Units 1 and 2 by mid-1997 and Units 3 and 4 in 1998. After a postponement of the deadline and further $14.5 million emergency funding from the EU, the Bulgarian government has refused to close the partially upgraded plants it

condition of closure may well jeopardise access to international funding in the future.

In the case of the VVER 440/213 design, a total of 87 safety issues were identified. Most importantly, the partial containment provided by the bubbler-condenser system requires structural reinforcement and the emergency feedwater systems may be vulnerable to common-cause failure due to their physical proximity within the turbine hall. The instrumentation and control system was found to be outdated, labour-intensive and of questionable reliability. The analysis does not condemn the VVER 440/213, although certain risks, such as fire hazard, were felt to be uncomfortably large. Some potential risk scenarios might require relatively costly modifications, but retrofitting many improvements would be feasible and may be economical given the good operating record of many reactors of this design. More extensive upgrades, in line with Western norms for defence-in-depth, were not, however, judged to be economic, hence the recommendation that these reactors should not operate for the entirety of their design life.

The VVER 1000 model is similar in design to Western PWRs, including for instance a containment system, and hence safety concerns have been less fundamental. Investigation has been primarily centred on quality of manufacture and reliability of equipment in operation rather than on the design, although some engineering solutions have been questioned. Observations of structural instability of some fuel assemblies and apparently related difficulties with control rod insertion have been noted,[37] and investigations continue into the possibility of a design flaw. Consensus was reached on the identification of 84 safety issues, but the assessment concluded that modifications to upgrade the reactor to international standards would be both possible and economical. It was therefore recommended that maintaining the reactors for their design life should be envisaged.

The strategy of the programme, based on design considerations not operating record, was for the international community to focus its long-term activities exclusively on the VVER 1000. It was implicitly assumed, without reference initially to the economic and social consequences, that the older models would be closed by their respective governments once the risks had been revealed, and that they would therefore require only short-term emergency intervention. The Western strategy is only one of maximum risk reduction if the older plants are indeed closed, but this appears increasingly unlikely for the practical reasons which were largely overlooked in the early 1990s. Without their closure the technological aspect of the Western strategy amounts to the prioritisation of largely hypothetical risks

remains dependent upon. The two older units are now scheduled to operate until 2003 and the newer ones until 2010. (Pavlov 1998:52).

[37] The problem has manifested itself after two or more years of operation at Balakovo, Zaporizhia, Kalinin, Kmelnitsky, Rovno and South Ukraine. (NEI 1997).

at the newest and least hazardous plants over the serious concrete deficiencies persisting at older plants, which may now operate for another ten years or more. This approach has the potential to alienate recipients of aid who are unsurprisingly inclined to view solving hypothetical problems as a luxury.

4.4 Safety Upgrades

The generic design studies have been used in conjunction with site-specific assessments conducted by the IAEA, the NSA, and WANO or through bilateral assistance programmes to prioritise technical initiatives for each plant willing to participate. The resulting initiatives are legion (NEI 1997), involving considerable expenditure through the international agencies, direct bilateral assistance and commitments made by the operating countries.[38] Planning between programmes is essentially independent, and it would be reasonable to question the degree of meaningful co-ordination which is possible under such circumstances, despite the assistance of the G-24 Nuclear Assistance Co-ordination Group.

Some clear technological safety priorities have been addressed despite the expense, while there has been relatively little progress on others, particularly in cases where a specific modification could be interpreted as a licence for life extension of ageing plants. Operating states would generally have to fund these inherently expensive long-term upgrades themselves. As an example of the prioritisation process, the IAEA's VVER 440/230 project, combined with initial site visits, identified reactor pressure vessel welds as being critically weak in many cases due to embrittlement through continuous irradiation. An international programme of annealing these welds to restore their ductility was initiated immediately and is now largely complete.[39] However, providing containment in order to comply with the defence-in-depth approach is a very much more difficult and expensive prospect.[40] Upgrading limited emergency core cooling capacity in response to doubts as to the integrity of primary cooling circuits is similarly problematic.[41] International funding, which was quickly provided for the annealing programme, is unlikely to be available for the latter long-term projects.

The preference of recipient countries is for equipment and capital projects capable of making direct, concrete and immediate improvements to address obvious problems. The insistence of some donors on extensive safety reviews addressing theoretical dimensions of risk has appeared to the recipients to be

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[38] For instance, Rosenergoatom in the Russian Federation is involved in twelve international safety programmes which require Russian implementation of 420 safety projects estimated to cost $500 million. (US DoE 1997).
[39] Only Kozlodui 4 and Medsamor 2 remain to be treated as of late 1997. (IAEA STI/PUB/1034 1997).
[40] Bohunice in Slovakia is developing a design for containment upgrading which others are prepared to consider, but implementation is likely to be protracted. (US DoE 1997).
[41] As of late 1997 only Bohunice had added an additional feedwater system outside the turbine hall, although plans exist for Novonoronezh and Kola in the Russian Federation and Kozlodui in Bulgaria. (NEI 1997).

missing the point and causing unnecessary delays.[42] Complaints have arisen that funding is primarily largesse provided through Western government contracts to their own consultants or nuclear industry contractors, bypassing considerably less expensive local expertise and industry despite the pressure on scarce resources. This has naturally been perceived as both patronising and self-serving, although the early misunderstandings on both sides are, in many instances, gradually evolving into more constructive working relationships.

On-going assistance with funding for repair and maintenance or for payment of wage arrears, with spending prioritised locally, would be valued highly by recipients, but is not generally provided. Capital expended on costly safety upgrades could fail to result in real improvements in safety, and therefore be wasted, if funds are not available for running costs, but the loss of direct Western control over spending which that would entail is considered unacceptable to donors aware of the possibility that funds might be diverted. Such concerns bring into question the strategy ostensibly chosen to reduce risk through inherently costly technological intervention. It is then reasonable to ask whether a different approach might make a greater contribution to reducing the overall risk than an expensive technical programme fraught with political and economic conflicts which may undermine its efficacy.

4.5 Probabilistic Safety Assessment (PSA)

A significant development of the IAEA technical approach is evident from the early 1990s with the emergence of guidance relating to the use of PSA (IAEA SS 106 1992). The focus remains technological, but the assessment method shifts from traditional determinism to an analysis based on probability. Safety analysis based on PSA, which has become feasible due to the vast increase in computing power since the 1980s, has rapidly become a ubiquitous tool in the West at the national level in order to provide the basis for definitions of adequate safety margins for the defence-in-depth approach (NEA/CNRA/R(95)2 1995). The methodology has been continually extrapolated in the attempt to maximise its supposed predictive ability.

PSA methodology uses a component reliability database and a comprehensive engineering model of the system to derive quantitative safety margins. The probability of each potential component failure is propagated through the model of the system, allowing a figure for the overall probability of each undesirable outcome to be calculated. Where an arbitrary maximum probability of a safety incident is exceeded, it must be reduced by substituting, subtracting or adding technological components until the

[42] There is considerable variation between donors on this point. European donors and their collective agencies, such as the NSA at the EBRD, prefer to fund the purchase of equipment, while Americans are more likely to fund operational safety initiatives or PSA analysis. (Court of Auditors 1997).

model yields an overall accident probability deemed to be acceptable by the regulatory authority.[43]

The use of mathematical probability in this way is controversial. Proponents claim to have revolutionised the understanding of technological safety, allowing concentration of resources on elements identified as safety critical in order that resources be employed much more effectively. PSA methodology represents a proactive approach to safety, allowing potential problems to be anticipated and mitigated. It is therefore claimed as evidence of a significant shift in attitude, according greater emphasis to safety as demanded by the Western public. In the Eastern context it is argued that PSA can greatly enhance the ability to target scarce resources at the most urgent safety concerns. There is clearly some merit in these arguments, but there is also a significant contrary case to answer.

Opponents argue that the use of simple component failure data, some of which may have been derived in the laboratory rather than *in situ*, can give little insight into the probability of failure for the system as a whole, even on a purely technical level. Components may affect each other's performance during operation, or they may fail to operate correctly in syncrony rather than failing outright. Operating histories can be used, but may be incomplete. Components may age at different and unpredictable rates which, arguably, cannot be modelled accurately.[44] Some safety relevant sequences of technical events may be absent from the model due to oversight, but of most significance is the absence in the model of the human components of the system for which no reliability database exists.[45]

Human behaviour cannot be modelled quantitatively in this way, nor can the influence of managerial and institutional arrangements. These factors clearly influence the confidence one may reasonably express in the probabilistic results of the analysis, which are not directly testable and can be neither proved nor disproved by the record of operating experience. It is possible to argue that the results are largely meaningless, although it would perhaps be more accurate to describe them as narrowly technical in their scope and applicability. The modelling process undoubtedly serves to enhance the depth of understanding of the engineering system, but its quantitative predictability is limited and should not be pursued beyond what is justified by the initial data.

The application of safety assessment based on PSA to Eastern reactors began in the early 1990s with the

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[43] INSAG recommends that the probability of severe core damage should not exceed 10^{-4} events per plant operating year. New plants with advanced safety features should seek to achieve probabilities no greater than 10^{-5}, such events per operating year. Plants where the estimated core damage frequency exceed 10^{-3} events per year should be closed immediately. (75-INSAG-3 1988).

[44] This has become a significant issue in the West for several plant designs.

[45] Research by INPO suggests that 65% of system failures at American plants involve human error and 51% are caused by human error. Hardware design deficiencies were thought to be responsible for only 32% of significant events. (Heyes 1995).

Barselina Project, a joint Swedish, Russian and Lithuanian endeavour to transfer methodology developed for the Swedish Barseback plant to the Lithuanian RBMK plant, Ignalina. A Level-1 assessment, which is the most common at the national level in the West, was undertaken to identify and assign probabilities to sequences of events which could lead to core damage. Such a study is intended to allow resources to be targeted towards upgrading components critical to the sequences for which the probability of core damage is identified as being unacceptably high (IAEA SS 50-P-4 1992). The Level-1 safety assessment was completed at Ignalina in 1996 (EBRD (1997) and a similar project begun jointly by the UK, USA, Sweden and Russia at the Leningrad RBMK plant at the same time. Plans exist eventually to undertake such an analysis for VVER 1000 reactors, following on from the qualitative assessments being currently undertaken, but there is apparently no prospect for its application to either type of VVER 440.[46]

A Level-2 assessment, which is planned for Ignalina, will prioritise sequences of events leading to core damage with respect to the probable magnitude and frequency of projected radioactive releases. It is intended to allow a further refinement of the resource targeting process specific to the prevention or mitigation of such releases (IAEA SS 50-P-8 1995). A Level-3 assessment, a very recent development of the PSA methodology, is used to further prioritise accident prevention and mitigation measures according to the potential impacts of radioactive releases on public health and the environment (IAEA SS 50-P-12 1996). As yet there are no plans to conduct such an assessment at an Eastern European reactor.

There are significant drawbacks to the application of this methodology in Eastern Europe, above and beyond the general criticisms already expressed (Foss unpublished). In technical terms, the necessary component reliability database is not available, and extrapolation from even the most closely related Western data would be a very poor substitute. The impossibility of quality assurance at the procurement and construction stages, amply expressed by frustrated construction managers at the time, is relevant here. The quality of the components is essentially unknown and is likely to be highly variable, even within a single plant. Designs such as the RBMK are also extremely complex and may therefore be difficult to model adequately. Even at a purely technical level, comparison of the results with those derived for Western plants is likely to be misleading.[47]

The effect of human error on the accident probabilities generated, particularly under the difficult economic and social circumstances of transition, is of such significance that the PSA results become highly suspect. Management is also seriously affected by transition, being forced, for instance, to choose between safety expenditure and payment of wages. Institutional arrangements for oversight are often

[46] Mr. Jahms, Manager, Riskaudit (Paris), personal communication.

completely novel and of doubtful effectiveness. The effect of these latter factors on the probability of an accident is likely to be both significant and adverse, but their unquantifiable nature precludes their inclusion in the probabilistic analysis.

PSA analysis, especially in an Eastern context, should be approached as a useful means of developing a valuable in-depth understanding of the engineering aspects of the system, but only a highly sceptical assessment of the numerical probabilities is warranted. The use of PSA as an aid to decision making is therefore limited. It would be reasonable to use it for the allocation of resources already committed for technical upgrades, but it cannot be used to prioritise technical aspects of safety in relation to other non-technical factors which may well be more significant contributors to the probability of an accident. The uncertainty is best addressed explicitly through qualitative value judgements.

4.6 Summary

- The traditional focus of national nuclear regulation has been technological, generally applied at the design stage. The goal has often been to achieve defence-in-depth by technological prescription. This approach has informed the international programme of the IAEA and other international agencies.
- The NUSS guidelines and related technical documents have acted as *de facto* international standards by which the IAEA and others have judged the safety of Soviet-era reactors.
- Only rarely can the Soviet-era reactors meet international safety standards, even through extensive and expensive upgrading. The VVER 1000 model is the only one considered by the international nuclear agencies and their state backers to be viable in the long term, and therefore is to be the only beneficiary of extensive upgrading. Other models will receive only short-term emergency assistance with a view to encouraging their early retirement. With closure increasingly unlikely, the strategy is not one of maximum risk reduction.
- Some safety upgrades are clearly an immediate safety priority. Other engineering interventions may be expensive and yet may not result in the desired risk reduction due to the effects of non-technical factors. It is therefore necessary to compare the potential effectiveness of resources targeted on both technical and non-technical aspects.
- The role of Probabilistic Safety Assessment (PSA) in nuclear regulation is increasing. As applied to the Soviet-era plants in particular there are difficulties with the lack of an accurate component reliability database. The quantitative results are undermined by failure of the PSA methodology to address the human factor, despite the adverse effects of transition which could be expected to magnify its significance. Results must therefore be treated with considerable caution.

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[47] This has been attempted for the Ignalina data. (Coles and McKay 1995).

5. FOCUS ON OPERATION AND MANAGEMENT

5.1 Developing an Understanding of the Human Factor

The traditional technologically deterministic approach is increasingly seen as an inadequate guarantor of nuclear safety in the Western states which developed it, particularly in the USA (Braithwaite unpublished). Since 1979, when both of the independent investigations of the TMI accident agreed that the weakest element in operational reactor safety related to human behaviour, safety as defined technologically has increasingly been perceived as a necessary, but far from sufficient, condition for the safe operation of nuclear plant. Indeed, there is also agreement that the potential value of reducing the human element of risk has been under-estimated in relation to the risk impact of improvements in safety hardware and in the design and manufacture of engineered systems (Kemeny 1979; Cox and Cox 1996). A wide range of human influences are increasingly recognised as crucial determinants of safety in terms of design, automation, operation, maintenance and management.

Ironically, regulatory reform in order to emphasise the importance of human behaviour in relation to technology, which would divert expenditure away from technological belt-and-braces requirements, would be perceived as deregulation and is therefore currently politically impossible in America. Despite the high capital cost of compliance with comprehensive engineering regulations, and the consequent detrimental effect on competitiveness in a deregulated electricity market, America cannot yet abandon its own technologically prescriptive system. It is, however, to some extent at least, encouraging the wider nuclear community to do as it says, not as it does (Rees 1994). Addressing the crucial human component of the overall accident risk is extremely unlikely to involve costs remotely comparable to those associated with large-scale safety system retrofits,[48] and evidence of the potential effectiveness of this approach in reducing the incidence of safety-significant events under variable political and economic circumstances is accumulating.

Attitudes are gradually shifting towards an appreciation of the significant role of human factors, but the change in perception is proving difficult to reconcile with the embedded culture of risk quantification. The result appears to be a rather awkward conceptual transition period, but with the potential eventually to deliver a much more comprehensive understanding of safety. The assessment of accident risk, although remaining firmly rooted in the complex technology, has recently begun to incorporate complementary techniques for the 'measurement' of the human contribution to overall risk in order to address persistent criticism of the methodology. Although the resulting quantitative data may be

[48] See qualitative cost estimates (high, medium, but mostly low) for the various human factor recommendations, the potential effectiveness of most of which was expected to be high (Birnie et al 1994).

disputed, techniques such as Human Reliability Analysis can offer valuable insight. Operational safety review, developed to include human factors as a crucial part of the system, is also an increasingly important process, both at the national and international levels. The recognition of safety culture as a prerequisite for stable operation in the long term is spreading, largely through the development of communication initiatives within the industry. However, the competition for limited resources with which to address the problems in Central and Eastern Europe and the FSU still appears to favour technology-based initiatives, despite their considerable cost and the existence of significant political, economic and social constraints on their effectiveness.

5.2 Human Reliability Analysis

Human Reliability Analysis (HRA) is an attempt to integrate human performance into a Probabilistic Safety Assessment (PSA) in recognition of the vital, yet largely unpredictable, role played by human actions. The validity of PSA results is dependent on both explicit and implicit assumptions as to human performance (Table 1) which have only recently begun to be tested by such methods as HRA. As yet, only 2–3 per cent of the international PSA budget is devoted to the study of human error (Heyes 1995), clearly less than is warranted by its significance given that by far the majority of causal factors for safety significant events have been identified as human rather than technical (Reason 1990a; Stanton 1996).

Table 1: Examples of PSA Assumptions Relating to Human Influences

Explicit Assumptions

- -Level of control room staff experience and general training
- -Types of inspections and quality assurance controls applied to maintenance
- -Comprehensiveness and accuracy of procedures (operations, maintenance and testing)
- -Ergonomics of man-machine interfaces
- -Quality of communications between plant personnel and control room staff

Implicit Assumptions

- -Ability to update procedures with plant modifications during plant lifetime
- -Sensitivity of organisation to changes of plant personnel, particularly management
- -Adherence of staff to procedures, technical specifications, quality assurance
- -Ability of management to resolve safety and economic conflicts acceptably
- -Ability to communicate important information effectively within organisation
- -Risk from errors of commission will be small compared to technical fault sequences
- -Risk associated with temporary operation outside limits used in fault modelling will be small (overall design margins are assumed to prevent significant 'cliff-edge' events)

Source: IAEA (1995). Human Reliability Analysis in Probabilistic Safety Assessment for Nuclear Power Plants. Safety Series No 50-P-10.

In the Soviet context, virtually all the explicit and implicit assumptions were violated. Although the control room staff were generally well qualified and experienced, they lacked specific safety training and were deliberately not informed about operational safety. Procedures and quality assurance were either underdeveloped or non-existent, and plant communications were strictly top-down although the operators were frequently more appropriately trained and experienced than their superiors (G Medvedev 1991). The ergonomics of man-machine interfaces was a non-issue in nuclear power as in everything else. The risk associated with certain errors of commission[49] was very significant for reactors such as the RMBK with characteristic rapid-onset 'cliff-edge' events. Many of the human influences identified contributed directly to the accident at Chernobyl, the probability of which had been estimated at one in a hundred million years of reactor operation using early PSA methodology (Bunyard 1988).

The ambitious goal of HRA is to predict the behaviour of operators in quantitative probabilistic terms, although even if this were achievable it would not reflect anything like the true extent of human influences.[50] HRA does not deal with the safety-relevant effects of individual actions performed at the stages of plant design and construction, design and commissioning of automated control systems, maintenance and repair or management. Most importantly it cannot gauge safety culture, but despite these significant limitations in scope it can provide valuable qualitative insights on the interface between operators and complex technology.

HRA is based on an understanding of different cognitive levels of human behaviour and their associated error mechanisms. Highly practised activities requiring little conscious thought are referred to as skill-based, less familiar tasks within the normal range of experience are described as rule-based and novel tasks where familiar rules cannot be directly applied are designated knowledge-based. Errors associated with skill-based activities are typically slips or lapses, and are generally recoverable, where plant behaviour is reversible, provided appropriate feedback mechanisms exist. Mistakes, associated with rule and knowledge-based activities, tend to be more serious and may be harder to recover from. An inappropriate sequence of actions may be chosen on the basis of an incorrect understanding of the system, and there may be problems of mindset in which operators persist in attempting to implement an inappropriate plan of action despite the availability of information inconsistent with their interpretation of plant behaviour.[51]

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[49] Errors of commission are those involving operator actions inappropriately undertaken, as opposed to errors of omission which are actions inappropriately not undertaken.

[50] A minority of human causal factors involve the actions of operators. (Reason 1990a).

[51] This was a significant factor at both TMI and Chernobyl. At TMI, the operators failed for several hours to diagnose a steam release valve stuck in the open position and misinterpreted error signals indicating the reactor was dangerously overheating. A very serious accident involving a potential hydrogen explosion was only narrowly avoided. At Chernobyl, the operators failed to appreciate that the reactor had exploded despite overwhelming evidence to that effect from eyewitnesses who sacrificed their lives to obtain the information.

PSA without a supplemental HRA tends to recommend more automation of plant control in an attempt to remove unpredictable human influences, particularly at the rule-based or knowledge-based level, from the tidy technical equations. Naturally this only relocates the sources of human error into the fields of maintenance and design of automation systems where human influences are even less predictable, but not necessarily of less significance in terms of the overall risk. Too great an emphasis on automation may render faults less detectable and may lead to the de-skilling of operators relegated to a routine role, thereby removing the potential for beneficial human interventions based on flexibility, ingenuity and an understanding of the plant. By encouraging operators to function at the lowest cognitive level for the vast majority of the time, their ability to respond appropriately in an emergency requiring rapid mental reactions may be reduced (Cox and Cox 1996).

HRA uses an understanding of different types of decision-making and their associated errors to suggest modifications of the interface between operators and machinery in order to reduce the likelihood of a non-recoverable accident. An understanding of human decision-making, to which HRA contributes, can allow PSA to target automation towards those areas where the risk of non-recovery from a misjudged action is assessed to be greatest. For instance, automated control can provide the initial negative-feedback response to a rapid-onset event, giving the operator more time in which to make a decision as to the appropriate sequence of actions. The right balance of automation and human control can facilitate actions which are desirable and minimise the opportunity for mistakes to lead to an irreversible incident. HRA has the potential to make a significant contribution to the analysis of safety relevant factors at plants in Central and Eastern Europe and the FSU, given the Soviet legacy equipment design with no thought for the end-user.

It would be of great value to assess the extent to which the explicit and implicit PSA assumptions are still being violated in view of the increasing use of PSA in the post-Soviet context. Of the explicit assumptions, there have been improvements in training, procedures and communications, but ergonomics is likely to remain a problem and inspections, maintenance and quality assurance are suffering from the economic effects of transition. The implicit assumptions are more difficult to judge. The most important violation in many parts of the FSU, although not necessarily in Central Europe, is likely to be the inability to balance safety and economic factors such as to accord sufficient priority to safety during the transition period.[52] HRA could highlight the extent of these difficulties and therefore justify the transfer

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Their persistent attempts to cool the reactor they thought was intact flooded the electrical systems for other units on site and very nearly caused a total loss of power to those reactors. (G Medvedev 1991; Stanton 1996).

[52] In addition to suffering fewer deprivations during transition, Central European countries also may benefit from the concern of their neighbours for the environmental integrity of their own territory. For instance, Austria has declared itself willing to provide up to $1 billion for safety upgrades at the newly commissioned Mochovce

of resources with which they could be addressed. There are also, however, additional human factors such as widespread alcoholism,[53] the undoubted significance of which is not likely to result in their inclusion in any official analysis.

5.3 Operational Safety Assessment

International operational safety assessments, conducted on request by various new and established international bodies, are becoming increasingly common as the understanding of safety broadens to include the human components of the system and the means by which they interact with the complex technology. The principal IAEA operational assessment programmes for specific plants are ASSET (Assessment of Safety Significant Events Team) and OSART (Operational Safety Review Team). WANO is also developing a comprehensive peer review system.

An ASSET mission investigates either single operating incidents or, more commonly, the long-term operating history of a plant, at the request of the management. Records are used to determine the number of incidents of safety significance, and those are then classified according to the International Nuclear Event Scale (INES) administered by the IAEA. Incident prevention programmes are then analysed in the light of the operating history. ASSET investigations were carried out by the IAEA until 1996 when a system of self-assessment was introduced, according responsibility for the gathering of data as to the direct and root causes of incidents and the determination of appropriate corrective actions to plant personnel. The ASSET team of international nuclear professionals would then undertake a peer review of the self-assessment and its conclusions.

The ASSET process may yield important information as to weak points which emerge in practice, potentially providing a valuable complement to the theoretical design analysis. The ability of the ASSET exercise to identify significant safety factors, relating to equipment, personnel or procedures, is, however, crucially dependent on complete and accurate records of operating history. Such records may exist in the former Eastern Bloc for the 1990s, although the nature or extent of information recorded may well be variable and comparisons therefore difficult. Earlier records are much less likely to be reliable. Most of the 38 ASSET missions have concentrated on recent operating histories, although some long-term studies have been undertaken (see Appendix 2).

OSART missions, of which there have been seventeen in the former Eastern Bloc to the end of 1998 (see

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plant in Slovakia which lies within 100km of the Austrian border.

[53] For instance, the management at the Zaporizhia plant in the Ukraine felt it necessary to introduce a permanent specialist counselling service to address the worst cases of alcoholism and other social problems. (Court of Auditors 1997).

Appendix 2 for dates and locations), are proactive assessments of operational safety, including the performance of both personnel and equipment.[54] The objective is to identify good practices and provide suggestions as to potential improvements, but without specific comparative reference to the safety performance of other plants.[55] The OSART process is one means of addressing critical deficiencies (see Appendix 2) in the conduct of operations, facilitating a view of safety balanced between the technical and the operational. They are more intrusive than reactive ASSET missions, and therefore appear to be less compatible with national pride. There have been no OSART missions in Russia to date, which is unfortunate since many of the most pressing safety issues are likely to be found where the erstwhile Soviet nuclear bureaucracy retains considerable control. If the process could be rendered more inclusive of the considerable pool of Russian technical expertise, it could perhaps become more acceptable.

In addition to the long-standing assessment services provided by the IAEA, WANO has begun to conduct private and confidential peer reviews, on a pilot basis from 1992 and formally since 1994. The WANO peer review programme is designed to allow members to compare their operational performance against best international practice. It is conducted by an international review team composed largely of staff from other member plants, rather than professional reviewers with potentially less current operating experience, and is supplemented by workshops and operator exchange visits between member plants in the East and West. The emphasis is on establishing channels of communication and thereby fostering the attitude that all parties involved can learn from each other (Braithwaite unpublished).

WANO uses the system of ten performance indicators, relating to safety, reliability and efficiency, developed by INPO in the American context, to compile data on the relative performance of all member plants world-wide.[56] This information is then analysed and distributed to members in order that each is able to see in which areas they have been more or less successful than their peers. Members are encouraged to submit event reports and ask questions through the WANO electronic communications system. If a particular instance of good practice or a successful solution to a generic problem is noted for one plant, the information is relayed to all members in order to communicate what is worth striving for at comparable plants in similar circumstances.

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[54] Pre-OSART design assessments were also performed at Mochovce in Slovakia and Temelin in the Czech Republic before the decision was taken to complete them. Missions were also undertaken at the Belene site in Bulgaria, at Zarnowiec in Poland and Gorkiy in the Russian Federation, perhaps contributing to the decisions not to proceed with completion at present. (NEI 1997).

[55] A follow-up study would generally be undertaken within two years in order to observe the extent to which the recommendations have been implemented.

[56] The performance indicators are Unit Capability Factor, Unplanned Capability Loss Factor, Unplanned Automatic Scrams, Safety System Performance, Thermal Performance, Fuel Reliability, Chemistry Performance, Collective Radiation Exposure, Volume of Solid Radioactive Waste and Industrial Safety Accident Rate. According to WANO, 99% of operating plants worldwide report at least 7 indicators and 77% report all 10. (Braithwaite unpublished).

The quantity and quality of communication between peers through the WANO network greatly exceeds that which occurs in the arm's-length IAEA review system, due to greater confidentiality and to the legitimacy gained by WANO in the ten years of its existence.[57] The emphasis is on avoiding another serious accident which could lose the industry the battle for public opinion worldwide, a considerable incentive to help struggling plants improve performance. Reviews conducted under these circumstances appear to the reviewed to be less judgemental and more constructive. Comparisons are made not with an arbitrary standard set by those with different priorities and in a very different economic situation, but with the actual achievements of peers. The IAEA deliberately does not make such comparisons, but they have tremendous practical and motivational value which WANO is in a position to exploit.

5.4 Training and Procedures for Improved Safety Awareness and Performance

There are many current international initiatives designed to address the practical issues involved in operational safety, in recognition of the fact that technological improvements cannot be expected to deliver safety in the absence of sufficient experience and informed caution in the workplace. Human factor programmes include the development of formal operational procedures, symptoms-based emergency operating instructions and training centres using simulator technology. All are intended to regularise operations and increase safety awareness through communication. The emphasis on developing facilities and organisational structures in partnership with local operators is a particularly positive aspect. The track record of this direct approach in the parallel development of nuclear materials control is demonstrable (Allison et al 1996).

Formal written procedures are intended to reduce the vulnerability of plants to the considerable variation in operator experience both within and between plants. Retaining sufficient experienced staff has been a chronic problem, particularly in the non-Russian FSU. It is therefore considered advisable to standardise the approach to routine tasks in order to address the risks associated with less experienced operators undertaking tasks without guidance or with more experienced individuals tempted to improvise, perhaps recklessly. This form of additional control is likely to be particularly important for plants lacking accident-mitigating defence-in-depth characteristics or where there is the potential for rapid-onset 'cliff-edge' events.[58]

Prior to TMI, Emergency Operating Instructions (EOIs) were event-based, meaning that the operators

[57] That credibility may have been compromised by the publishing of a WANO assessment of the remaining Chernobyl unit in contravention of the confidentiality principle. It is unclear why the document was published.
[58] Pilot projects for the development of written procedures have been established with the assistance of the US

would first identify the cause of an event then respond to it. Like written procedures for undertaking common tasks, event-based EOIs attempt to regularise the responses of operators by thinking through a range of potential incidents and providing the answers to foreseeable events in advance. The major difficulty, however, is the correct diagnosis of rare events under pressure in order to apply the appropriate set of instructions. Symptoms-based EOIs, whereby the deviation of certain parameters such as pressure, temperature or water level trigger a specified negative feedback response, were subsequently developed to address this difficulty. By calling for a relatively simple response to specific parameter changes, the potential for initial critical error is reduced. With the reactor stabilised, the operators should then have more time, under less pressure, to determine the actual cause and deal with it. Merely drafting EOIs may help to raise awareness of the safety critical aspects of abnormal operations.

Where EOIs existed in the Eastern context they were event-based, but symptoms-based EOIs are now being developed for pilot plants of each Soviet design.[59] The pilot plants are intended to disseminate the generic knowledge to other similar plants where site-specific guidance can then be developed by local personnel. Responsibility for co-ordination of working groups[60] passed to WANO in 1997.

Training of operators using simulator technology is well established in the West, the idea being to provide practical experience of a wide range of operating conditions in advance of assuming responsibility for an actual plant. The novelty of unusual conditions is reduced and appropriate operational responses can be internalised. Simulators can be either full scope, for which a full-scale replica of the control room is required, or analytical, based on computer graphic representations of plant systems. Full scope simulators have the advantage of providing physical familiarity with the control layout, but are obviously more expensive. Simulators have not generally been available in the former Eastern Bloc, although a higher level of formal technical education was required of Soviet operators instead.[61] The US Department of Energy (DoE) and the Russian Institute for Nuclear Power Operations (VNIIAES) have established a joint venture, with technology transferred to VNIIAES, to produce full scope simulators for the Kola and Kalinin plants and analytical simulators for Balakovo and Novovoronezh. In the Ukraine, the DoE is assisting with the provision of full scope simulators for

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Department of Energy at Balakovo in the Russian Federation and Zaporizhia in the Ukraine. (US DoE 1997).

[59] In the Russian Federation Novovoronezh (VVER 440/230), Kola (VVER 440/213), Balakovo (VVER 1000) and Smolensk (RBMK) are the pilot plants, while in the Ukraine, Rivne (VVER 440/213) and Zaporizhia (VVER 1000) have been chosen. The remaining Chernobyl unit (RBMK) is being addressed as a separate project.

[60] The international component of a working group sponsored by the US Department of Energy would typically be composed of INPO personnel, staff from nuclear utilities, and technical personnel from American national nuclear laboratories.

[61] Operators in Russia required a degree in engineering, and generally had a considerable depth of technical ability, but did not receive safety training as such on the grounds that safety was not an issue for the supposedly superior Soviet nuclear technology. American operators needed only a high school diploma, but were subjected

Khmelnitsky, Rivne and South Ukraine and an analytical simulator for Chernobyl.

Regional training centres, some of which will incorporate the simulator technology, have been established at Balakovo and Smolensk in Russia and Khmelnitsky in the Ukraine[62] with bilateral assistance from the USA. The initial phase of course development was based on the work of INPO in America, which prepares training programmes on behalf of the Nuclear Regulatory Commission (NRC), in conjunction with local personnel. Passing on the resulting guidance is now largely a local responsibility. The intention has been to provide the seed resources, in terms of finance, technology and expertise, necessary to initiate a training programme for the benefit the staff of all the plants in the area.[63]

5.5 Management for Safety Culture

It is clear that the actions of a very wide range of individuals affect the safety of nuclear installations. Operators clearly have a pivotal role, but the contribution of designers, construction and maintenance workers, quality assurance personnel and many others are also vital. Indeed, it appears that this 'supporting cast' is over-represented in terms of incident causation in comparison with operators (Reason 1990a), suggesting that the perceived safety-significance of their less direct actions may be disproportionately low. It is therefore necessary to foster the internalisation of a general attitude of caution with regard to the actions of all the human components of the system in order to avoid the disruption, and potential hazard, caused by avoidable incidents. Such an instinctive attitude of conservatism with regard to safety is termed 'safety culture'[64] and has become a major preoccupation of national nuclear regulatory authorities as well as of the industry itself, concerned as it is to secure its own future by achieving public acceptability.

The prioritisation of safety in relation to other operational goals for all categories of staff requires the active involvement of management, since employees generally seek to fulfil the goals they perceive to be of most value to their employers in order to gain career advancement. Thus operators and others convinced that productivity, and therefore profit, is the real management priority, and sure that they will be rewarded for maximising it in the short term, are less likely to make decisions which are conservative with regard to safety (Newton 1995). A management which accords only nominal or lukewarm support

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to increasingly rigorous training as public concerns as to nuclear safety developed.

[62] The Ukrainian centre is considerably less well developed than the Russian ones, but Russians and Ukrainians refuse to share facilities. (CP Haigh, Magnox Electric, personal communication).

[63] By the end of 1996 approximately eight hundred individuals had undergone training.

[64] The concept of safety culture was explicitly developed by the International Nuclear Safety Advisory Group (INSAG) at the IAEA, which defines it as 'that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.' (75-INSAG-4 1991).

to safety is therefore unlikely to achieve it at all, but, conversely, a management obviously committed to safety can often establish a culture of safety quickly and effectively (Rees 1994).

INPO has very effectively exploited the potential of management involvement in America by creating a peer group of utility company chief executives, the annual meeting of which serves as a very effective forum for the application of peer pressure. The performance indicators for all plants are used to devise rankings and these are revealed to all members, all of whom appreciate the importance to the nuclear industry of avoiding another accident and all of whom wish to avoid being exposed to their peers as the weak link. The motivational effect is considerable, leading embarrassed CEOs to return to their companies insisting that the performance indicators be improved (Rees 1994:104).

The result has been that safety relevant incidents in America have fallen by more than a factor of 20 in twelve years and unplanned automatic shut-downs have decreased by an order of magnitude, while the average unit capability factor, that is the achieved percentage of the theoretical maximum energy generation a plant should be capable of supplying to the grid, has simultaneously increased by 20 per cent.[65] Managers have discovered that an emphasis on incident-free operation has created the conditions for maximising profitability in the longer term by avoiding very costly unplanned shut-downs, a factor that will be crucial in determining the competitiveness of nuclear power in the newly deregulated American electricity market.[66] Performance indicators for other OECD states have also improved considerably as the lesson as to the importance of human factors derived from the analyses of TMI and Chernobyl has been applied to operations generally.

The safety culture approach is universally applicable, but has particular significance for the nuclear safety debate in Central Europe and the FSU. Where there are notable safety deficiencies, either with regard to defence-in-depth or the potential for 'cliff-edge' events, and the probability or consequences of an accident are therefore likely to be unduly large, it is clearly of the utmost importance that decision-making be undertaken with a view to incident prevention. Lack of safety culture has been identified as a persistent and critical feature of the regime at several Eastern plants, although the situation has generally improved since the early 1990s.

In 1992 the Norwegian Bellona Foundation found the Kola plant in the Russian arctic to be in an appalling condition of disrepair (Nilsen and Bohmer 1994),before the worst privations of economic

[65] The average number of significant events per unit has fallen from 2.38 in 1985 to 0.10 in 1997 according to Nuclear Regulatory Commission data. (NEI 1998; Thomas 1998).

[66] For a dramatic account of the reversal of fortunes of the Philedelphia Electric Company (PECO) after the crucial challenge which confirmed the authority of INPO see Rees (1994) and Thomas (1998).

transition and the development of the non-payment crisis. They found large cracks in the walls and little functioning illumination. Loose cables and wires were in disarray. The reactor hall was scattered with waste and showed significant levels of radioactivity. Contaminated equipment was discarded in a corner, cordoned off from the thoroughfare with a piece of string. The floors were lined with flammable material, which would give off toxic fumes if ignited, yet there was no fire extinguishing equipment, with the exception of a couple of shovels and some rusty buckets, and smoking was not prohibited. The diesel backup generators were poorly maintained, leaving the plant vulnerable to loss of onsite electric power.[67] The emphasis on safety culture has already resulted in considerable improvements to these deplorable conditions,[68] although many less superficially obvious issues indicative of the management attitude to safety remain to be addressed .

In 1991 the IAEA had noted even worse deficiencies at Kozlodui in Bulgaria where the probability of a serious accident, potentially arising from any one of a range of critical defects, was very significant (IAEA GOV/INF/657 1991). The Bulgarians had been abruptly left in charge of a plant previously run by Russian operators from a room to which local personnel did not even have access. The departing Russians had handed them the key and wished them luck. Seven years later the plant has been repaired and upgraded, but the crucial feature of its greatly improved condition and performance is felt to be the attitude of staff and management developed through extensive contact with their peers from plants in other nuclear states. Problems remain, but no longer of anything like their previous gravity.[69]

Progress is, however, uneven, as illustrated for instance by the recent criticism of Ukrainian plant managers by Oleksandr Smyshlyayev, the head of the Ukrainian nuclear control administration. Mr Smyshlyayev despairs of the apathetic attitude of managers towards flagrant violations of safety rules, accusing them of 'a systematic unwillingness...to adhere closely to nuclear and radiation safety requirements'. According to Mr Smyshlyayev, plants continue to exhibit serious deficiencies of safety culture as managers refuse point blank to implement safety enhancing measures they themselves have devised. Many are persistently in breach of their licence conditions.[70] If the attitude of management towards safety issues is neutral, or negative, then extremely expensive upgrading is unlikely to have the desired effect on safety standards.

[67] Indeed the generators failed to respond to exactly this circumstance in February 1993 during a power outage lasting two and a half hours. The reactor core was cooled only by natural circulation and may have come perilously close to a meltdown.

[68] Mr. Jahms, Riskaudit (Paris), Mr. Richard Bye, Nuclear Installations Inspectorate (London) and Dr CP Haigh, European Support Group, Magnox Electric - personal communications.

[69] CP Haigh, Head of European Support, Magnox Electric, personal communication.

[70] At the Zaporizhia plant, some equipment, including vital control devices approaching the end of the service life, had not been checked for more than 10 years, in violation of safety rules. Management at the Rovno plant tried to put the first generating set back into operation after repairs without checking for metal defects. (East

Safety culture is likely to be most difficult to introduce where it would make the greatest difference, in plants where there are obvious risks and little management support for change. The concept of safety culture rests on the assumption of individual responsibility for all safety-critical aspects within the sphere of awareness, that is seeking to address all safety issues of which an individual is aware whether or not the problems lie within their prescribed set of duties. However, few employees are likely to want to take responsibility for safety if their best efforts are unlikely to achieve it, especially if they may be victimised for bringing issues to the attention of those best placed to deal with them.[71] It is therefore necessary to encourage management to management communication to the same extent as communication between operators. The involvement of all staff in the development and implementation of an Employee Concerns Programme (Stier, et al 1995), which would require only very modest funding in comparison with the scale of expenditure on technical upgrades, could be potentially very valuable.

The most important difficulty in applying the safety culture approach will undoubtedly be the lack of resources available in some of the transitional economies, particularly in Russia and the Ukraine. The prioritisation of safety over production implies greater costs in the short term at a time when current running costs often cannot be met. Cogent arguments that a conservative safety policy is likely to reduce the need for more expensive repairs in the longer term may provide little consolation to those whose horizons have been foreshortened by extreme economic pressure, particularly in light of the 1998 crisis. It is, however, important to bear in mind that technical upgrades, for which funds have been donated, are often very costly. Indeed, concentrating donated resources on laying the foundations for an improvement in safety culture, both by seeking to change attitudes through communication and by ameliorating the on-going state of crisis management, perhaps by partially funding operating costs such as repair and maintenance, would be both less expensive and most likely more effective (Birnie et al 1994). The former is indeed occurring, but the current donor bias towards capital expenditure rather than operating costs represents a barrier to the latter.

If they can build and maintain sufficient industry credibility, WANO may eventually attempt the difficult task of building a global process analogous to that undertaken by INPO in America, although not explicitly self-regulatory in the manner of INPO's activities. The WANO safety review process is already explicitly comparative in terms of plant performance indicators, unlike that of the IAEA. The biennial general meeting, at which senior executives representing members discuss progress, challenges and the future direction of WANO, could evolve into a suitable forum for the comparison of performance

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European Energy Report 82:25 1998).

[71] The treatment of whistleblowers has been, and often still is, a problem throughout the industry globally. (See NEI Communications Update, 28/09/98 for a discussion of NRC concerns in the American context).

indicators. However, where many countries with heterogeneous economic and political circumstances are involved, fostering the development of a peer group through which peer pressure on management could be applied is likely to be problematic. Unlike America, where the nuclear industry is in the private sector, most states retain bureaucratic control of nuclear energy, which may dilute the substantial motivational effect of the industry's fear for its own future. Without a means effectively to concentrate safety performance pressure on those in control, it is difficult to influence those further down the hierarchy who answer to their own superiors and not to outsiders.

The IAEA and other official organisations are likely to be less successful than WANO in fostering safety culture through management guidance.[72] One would expect the abstract formal approach, developed to counter theoretical risks in the rich world, to carry less weight with both operators and management than the concrete and pragmatic suggestions of their extended peer group made in confidence. Indeed, management guidance from the IAEA, or by other public bodies, may well be taken as unwelcome political interference, as judgemental and paternalistic. Engineering advice is perceived as relatively objective, as less value-laden and therefore more acceptable than management pronouncements. The challenge is to deliver the message on management which has emerged from the analysis of previous accidents in an acceptable way, countering the argument that such a concern is a superfluous and unaffordable Western luxury.

5.6 Summary

- The adequacy of the traditional technologically deterministic approach to safety has been challenged by evidence of the importance of human factors. Means of assessing and addressing the risk posed by the human components of the system are therefore being developed and applied throughout the nuclear industry.
- Human Reliability Analysis (HRA) is a potentially powerful technique for incorporating the human element into risk assessment, although attempts at quantification are ill-founded.
- Operational safety assessments have been undertaken by a variety of different bodies at virtually all Soviet-era plants, with retrospective missions being the most common. WANO comparative peer reviews against a set of ten industry-wide performance indicators appear to have the most credibility and therefore the greatest potential for achieving results.
- The regularisation of operations and training of personnel have been considered a priority and are being addressed through the establishment of pilot programmes and training facilities for each type of Soviet-era reactor design. The inclusion from the developmental stage of local personnel, who will

[72] For a record of some experiences see IAEA TECDOC/821 1995.

ultimately be responsible for disseminating the benefits, has been particularly important.

- An emphasis on safety culture has had a dramatic effect on safety statistics in the OECD. Ensuring that decisions taken by all personnel are conservative with regard to safety could have an even greater importance where technological or operational safety margins may be thin, as is often the case in the former Eastern Bloc. A shift in donor funding priorities away from large-scale capital expenditure on technology and towards the development of safety culture is required.

6. FOCUS ON NATIONAL INSTITUTIONAL ARRANGEMENTS

6.1 The Rule of Law and the Control of Arbitrary Power

A legally constituted institutional framework for the control of the nuclear sector has been required at the national level in the West since the introduction of a civilian nuclear industry. The current minimum requirements for regulatory independence, accountability and transparency are the result of an evolutionary process over the intervening decades,[73] although there is still significant variability between states. At one end of the spectrum is the United Sates with its technologically prescriptive system, emphasising transparency in a legalistic culture by minimising individual discretion. At the other end is the United Kingdom where the focus has been primarily technological, but freedom for innovation in meeting general standards is considered important and regulation is therefore less prescriptive and inevitably less transparent (Heyes 1995:1027). There is clearly no consensus as to the appropriate balance between transparency and discretion, with the exception of general agreement that either extreme is likely to be counter-productive. Transparency enhances clarity and predictability, while discretion permits an intelligent evaluation of variable contextual circumstances. It is the task of the legal basis for regulation to provide for the discretionary element to be exercised in an accountable manner.

Nationally, it is expected that nuclear power would be regulated by a formally constituted body, which is independent and thereby intended to be objective in its judgement and in the execution of its duties. The goals it would seek to achieve and the priorities it would consider in so doing, for instance public and employee health and safety, would generally be set out in its constitutive legislative instrument. The regulatory body would control individual plants in the public interest by means of a legally-based licensing process, such that the standards required would be clear and would be the subject of periodic compliance review (NEA/IAEA/EC 1997). The body would expect to be accountable to an independent judiciary at least for the manner of its decision-making, which must be reasonably transparent in order to be justified in response to a potential challenge, and in some jurisdictions also for the proportionality of its chosen measures in relation to the predetermined goal. It would expect to be ultimately accountable to the legislature for the balance of priorities it has achieved in the public interest (Ogus 1994).

The requirements for independence, accountability and transparency are intended to maintain the rule of law in relation to the regulatory process. By subjecting all, including those in positions of control, to

[73] For instance, in America the Atomic Energy Commission (AEC) originally had the dual role of promoting and regulating the nuclear industry. Public pressure over the obvious conflict of interest in a controversial area led to the 1974 breakup of the AEC into the Energy Research and Development Administration (now part of the Department of Energy) and the independent Nuclear Regulatory Commission (NRC). Concern over the influence wielded by powerful vested interests has increased pressure for transparency. The debate as to custody of the public interest continues.

common legal standards, the rule of law aims to prevent the arbitrary exercise of power and the abuse of privileged position.[74] Citizens are to be protected in relation to the organs of the state or powerful vested interests by regulatory bodies whose own activities are legally circumscribed in order to prevent them balancing priorities in an arbitrary or secretive manner (Boustany 1998). This ideal is incompletely achieved to a variable extent in Western states, having been a persistent cause for public concern in relation to the nuclear industry for some thirty years. In the Soviet Union, however, it failed to influence a political culture based on the exercise of unconstrained executive power in any meaningful way (Carothers 1998).

The nuclear industry in the Soviet Union was never legally constituted and was therefore a law unto itself (Kanygin 1996). The public interest was thought self-evidently to lie in productivity alone in order to achieve maximum industrialisation (G Medvedev 1991), hence there was no regulatory process to seek a balance between productivity and health and safety or environmental integrity. With no collective entities independent of the state this position could not be effectively challenged. The successor states have been left the monumental task of building regulatory institutions and processes, binding them into a legal framework and, most dauntingly of all, endowing them with public credibility. The rule of law, which played no part in the development of the former Eastern Bloc, is now being encouraged in societies where the population remains deeply sceptical of the notion that law could serve any interests other than those of the powerful (Tolstaya 1996).

6.2 The Extent of Post-Communist Legal and Institutional Reform

Since the collapse of the Soviet Union, both the Soviet successor states and the former client states have almost all introduced extensive legal and institutional reforms, although the process has not been uniform due to the diversity of legal positions prior to that time. Central European countries had generally placed their nuclear industries on some form of legal footing during the decade between the late 1970s and late 1980s (see Appendix 3), whereas the industry and its colossal bureaucracy had no legal status in the Soviet Union. It therefore had none in the Soviet successor states. Moreover, of the successor states, only the Russian Federation, and to a minor extent the Ukraine, inherited any form of institutional framework for the control of the industry. Lithuania was dealt the task of drafting nuclear legislation and building completely novel institutions while simultaneously facing an exodus of qualified and experienced

[74] 'The rule of law can be defined as a system in which the laws are public knowledge, are clear in meaning, and apply equally to everyone... The central institutions of the legal system, including courts, prosecutors, and police, are reasonably fair, competent and efficient. Judges are impartial and independent, not subject to political influence or manipulation. Perhaps most important, the government is embedded in a comprehensive legal framework, its officials accept that the law will be applied to their own conduct, and the government seeks to be law abiding.' (Carothers 1998).

Russian personnel. Armenia found itself in a similar position once forced to restart its Medsamor plant.[75] It is not surprising that the countries of Central Europe are currently more advanced in this regard than those of the FSU.

A primary driving force for legal reform in many states has been the need to secure assistance, financial and otherwise, with upgrading older plants. Western contractors were generally unwilling to undertake complex projects in the absence of a comprehensive liability regime, fearing that they may expose themselves to potentially huge losses in the event of an accident at an upgraded facility (Nuclear Energy Agency 1994). The states of the former Eastern Bloc were not initially signatories to the 1963 Vienna Convention on Civil Liability for Nuclear Damage and hence liability would not have been automatically channelled to the operator. States wishing for assistance were therefore effectively required to become signatories and to amend their domestic legislation in order to reflect this international commitment. In order for operators to be eligible for the required insurance cover, it was also necessary to place the entire industry on a secure legal basis complete with clearly defined lines of responsibility and mechanisms designed to achieve accountability.

The process instigated a root and branch reform encompassing much more than liability for potential damage. All the states of Central and Eastern Europe and the FSU, with the exception of Armenia and the partial exceptions of Bulgaria and Slovakia, have passed comprehensive nuclear legislation in the mid-1990s (see Appendix 3). Each has introduced a regulatory body with specific responsibility for nuclear safety,[76] and most are at least nominally independent of the nuclear development process. Licensing of all civilian nuclear activities is to be universally required. Only Russia, which has considerable indigenous nuclear expertise and is therefore not dependent on assistance, has not yet ratified the Vienna Convention.[77]

6.3 Assistance with the Development of National Regulatory Mechanisms

Assistance programmes in this field have strong international and bilateral components. Of the international nuclear bodies, the Nuclear Energy Agency (NEA) and the IAEA have been most active, often acting jointly. The NEA, which has documented the development of nuclear law in the countries

[75] It had been closed in 1989 due to seismic risk, but reopened in 1995.
[76] The Inspectorate for the Safe Use of Atomic Energy in Bulgaria, the State Office for Nuclear Safety in the Czech Republic, the Hungarian Atomic Energy Authority, VATESI in Lithuania, Gosatomnadzor in the Russian Federation, the National Commission for the Control of Nuclear Activities in Romania, the Nuclear Regulatory Authority in Slovakia, the Slovenian Nuclear Safety Administration and the Ministry of Environmental Protection and Nuclear Safety in the Ukraine.
[77] Russia signed the Vienna Convention in 1996.

of the OECD for over twenty years,[78] is now conducting legal seminars intended to explain each aspect of the current Western regulatory model as well as analysing the process of its incorporation in the legal systems of Central and Eastern Europe and the FSU (NEA 1998b). The international legal guidance does not involve advice on the setting of specific technical standards, concentrating instead on the broad legal principles of regulation. Most fundamental is the balancing of risk and benefit through a licensing process allocating permission to carry out a potentially hazardous activity under the control of an independent regulatory body. That body would have the task of monitoring compliance with licence conditions and would have the power to take enforcement action in the event of specified breaches. The conditions of liability for damage would also be specified in advance (Pelzer 1997).

There is a clear division between the approach tailored to the Newly Independent States of the FSU and that targeted to the Central and Eastern European states, based on the aspiration of the latter to membership of the EU. For the states in the former category, legal control of the nuclear sector is an important part of the process of legal institution building generally, as they construct novel political systems to replace the provincial bureaucracy previously subordinated to Moscow. The process is in its infancy and hence cannot yet be expected to fully incorporate and implement sophisticated or prescriptive rules developed in a mature legal context. Intervention, referred to as regional information (NEA/IAEA/EC 1997), is therefore aimed at the eventual achievement of long-term goals. In Central and Eastern Europe, in contrast, the goal is compliance with the hard law of the EURATOM regime in the medium term in order to be considered for EU membership. The guidance, referred to as advanced training,[79] therefore amounts to a compulsory set of minimum conditions, with the expectation of concrete actions being undertaken immediately to achieve them. The Russian Federation is the sole regional non-participant in either forum.

In addition to the intervention of international bodies, Western national regulators have been heavily involved in the process of institution building for their counterparts in the former Eastern Bloc. The American NRC has had a particularly large role, focusing primarily on the Russian Federation and the Ukraine. Priorities include training regulatory personnel, advising regulators on legal reform, sharing experience of the operation of a licensing system, developing an enforcement regime, applying Western analytical methods such as PSA, and helping to build regulatory credibility by association. Much of this assistance is potentially valuable, but there is a danger that bodies such as the NRC may attempt to graft a prescriptive regulatory framework onto an underdeveloped legal and institutional system with which it is not compatible.

[78] For the latest version see NEA (1998a).
[79] NEA/IAEA/EC (1997). Advanced Training Seminar on Nuclear Law: The Convergence of Legislation in Central and Eastern Europe with EU and International Nuclear Law. Dubrovnik, Croatia, 25–29 August 1997.

Technologically prescriptive regulation, with its detailed and specific requirements covering all aspects of design and operation, is unsuited to environments in which technical improvisation has always been unavoidable. Under the Soviet system plant managers occasionally had to manufacture components on site if they could not procure them,[80] or endlessly repair what could not be replaced. During transition, debt has prevented plants from obtaining materials and equipment. Instead of basing regulatory requirements on technical specifications which it may well be impossible to meet, an approach setting only goals to be achieved while leaving the means of achievement to the discretion of management is likely to be more constructive.

By encouraging a certain amount of discretionary innovation at the level of the plant, the safety case for which would have to be approved in discussion with the regulator, it may be possible to build a positive relationship between the plant and the regulator. It may not be possible to reach abstract safety ideals in this way, at least not in the short to medium term, but it is conceivable that safety may be maximised to the extent achievable today in countries in a state of transition. This may well be the only means of endowing newly formed regulatory bodies with the authority they need to control the practices of an established industry.

6.4 The Extent of Compliance with the New Legal Order

So recent is legal reform that one cannot yet pass judgement on its effectiveness. The consequences attributable to changes in the legal regime, as opposed to the effects of political and economic factors, are generally difficult to disentangle without the benefit of at least a decade of hindsight (Carothers 1998). It could take even longer under the circumstances of economic transition in the FSU and Eastern Europe.

The EU has a strong incentive to confirm the effectiveness of the new arrangements before permitting the accession of new members. One would therefore expect Hungary, the Czech Republic and Slovenia, which are amongst the front runners, to receive the most support in the short term and to make the most rapid progress. Confirmation of their accession could be taken as evidence of a favourable risk assessment of the arrangements as they function in practice by those with access to the most information.

In the second rank, one would expect to find Slovakia, Lithuania, Romania and Bulgaria, all of which aspire to EU membership but will not achieve it in the near future. Preliminary agreements have been

[80] See for instance the comments of VT Kizima (1977), Head of Construction at Chernobyl, on technical improvisation due to lack of choice. *Radianska Ukraina* 29/10/77.

signed, but the process of restructuring has either barely begun or has yet to achieve credibility. These states would probably all be required to close plants as the price of membership[81] regardless of the success or otherwise of their legal reforms, although this may be academic given the length of time likely to elapse before any are judged to be ready for membership.[82]

In Lithuania, for instance, legal arrangements for control of the nuclear industry were entirely novel and there was a dearth of experienced local personnel to operate or regulate the Ignalina plant (Vilemas 1995). Advice and assistance, particularly from the understandably concerned Scandinavian countries, have been provided in relative abundance, but there are doubts as to the power of the regulator VATESI given that Ignalina provides more than 80 per cent of Lithuanian electricity (see Chapter 8) and a surplus that can be exported for hard currency. Openness has increased to a commendable extent,[83] but the distinction between regulator and promoter remains blurred even though VATESI is nominally independent.

At the far end of the effectiveness spectrum one would expect to find war-torn Armenia, the Russian Federation, which has a powerful and proud nuclear bureaucracy unused to submitting itself to the rule of law, and the virtually bankrupt Ukraine still trying to address the risks and consequences of Chernobyl. All are thoroughly entangled in the web of debt, particularly in relation to energy supplies, and none can afford adequately to finance their new regulatory institutions. All are suffering from an on-going crisis of governance which is exacerbating other structural problems (see Chapter 8). Much less reliable information is available in these states, particularly in the Russian Federation where nuclear information is due to remain an official state secret for another ten to fifteen years. Those who have revealed such information on environmental or other grounds have been prosecuted.[84] Some information as to the effectiveness of regulation has nevertheless emerged.

Gosatomnadzor (GAN) was once championed by President Yeltsin, but remains chronically understaffed and under-resourced, and has sometimes been denied access to plants by their management. It is heavily centralised and thus weak in the regions, especially in comparison with the colossal and entrenched Minatom (GAO/RCED-96-4 1995). Operators, who see Minatom as the sole guarantor of the vestiges

[81] With the exception of Romania where the Cernavoda reactor is a new CANDU,

[82] The plants judged to be the least safe on design criteria – Ignalina, Bohunice in Slovakia and the first four units at Kozlodui in Bulgaria – would probably be incompatible with EU membership, but most units are likely to close before 2010 due to age.

[83] Indeed the plant has its own website (http://www.iae.lt/iae/info) which includes information on monthly capacity factors, electricity production and incidents graded according to the international nuclear event scale. It even records average releases of radioactivity and the radiation reading at ground level.

[84] Alexander Nikitin, who co-operated with the Bellona Foundation in documenting the radiation risks posed by the Russian Northern Fleet base at Andreeva Bay, has been detained for over a year despite the fact that all the

of their traditionally privileged position, may view GAN as a threat to their livelihood (Popova 1993). Despite the obvious problems, the sites under GAN supervision appear to be better run than those, mainly military sites, to which it does not have access. It is clear that GAN benefits from the efforts of some very dedicated personnel, but the impact of regulatory reform is likely to be felt only in the long term, probably not within the design life of many Soviet-era plants.

The situation in the Ukraine has been highlighted by Oleksandr Smyshlyayev, the head of the Ukrainian Nuclear Control Administration, who has recently complained of flagrant violations of safety rules. He revealed that the energy ministry requested the Nuclear Control Administration not to link the start-up of generating sets to the implementation of measures to increase safety because of extreme conditions in the sector. Fortunately, the position of the Nuclear Control Administration was supported by the government in this instance, and the ministry asked to account for its behaviour. Nuclear industry specialists continue to doubt Ukraine's ability to maintain the proper safety standards at its plants. East European Energy Report (1998) 82: 25. As with Russia, instituting credible and effective regulation is likely to be a long-term project.

In unstable societies, individuals in positions of power may define their best interests narrowly, in terms of maximising personal gain during a tenure which is uncertain and probably short, rather than exercising their power in the wider public interest. Where there is no tradition of accountability it is even more likely. That such a situation prevails in parts of the former Eastern Bloc (Ledeneva 1998) is an indicator of general legal and regulatory failure in the states concerned. Greater stability may increase the perceived importance of longer-term social goals in comparison with immediate personal enrichment, but there is also a danger that it may allow corruption to become institutionalised. Ultimately, the state must choose to be bound by the law, however inconvenient this may be. It must instil this attitude in its component parts, and the managers of state organs must require the same standards of their staff. It is a matter of leadership in the public interest, which is particularly difficult in young democracies weakened by the upheaval of economic transition. Whether or not it is achievable may become clearer in time.

In order to build public credibility for the regulatory process it will be necessary to convince typical individuals that the system is prepared to serve their interests rather than merely those of the powerful. For the state to abide by the law, and be seen to be doing so, is only the first step in achieving a national culture of respect for the law. However, as Tolstaya (1996) explains, 'At the worst moments of Russian history, disrespect for the law has played a positive role...But when society grows accustomed to

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information was already in the public domain. His trial for high treason began in St Petersburg in October 1998.

viewing the very idea of the law with disdain, certain very important principles blur and the idea of a civil society is undermined.' Overcoming that unfortunate heritage of profound distrust for central authority will at best be a very long-term prospect.

6.5 Summary

- The rule of law as a means of curtailing the arbitrary exercise of power was not a feature of the Soviet system, particularly in the nuclear industry which was never legally constituted. It has fallen to the Soviet successor states and the former client states to devise an effective system of institutional control to defend the public interest.
- Legal reform in the former Eastern Bloc has been extensive, partially in response to pressure to comply with the international liability regime.
- The international nuclear agencies and nuclear regulatory bodies from Western states, particularly the NRC in the USA, have provided significant bilateral assistance to the new Central and Eastern European regulators, but there is concern that a complete regulatory framework developed in a Western context cannot simply be bolted on to underdeveloped legal systems.
- It is too soon to judge the extent of compliance with the new legal order but the signs are not encouraging in some countries, particularly the Russian Federation and the Ukraine. Compliance in states considered acceptable for membership of the EU will have to be much better. For regulatory institutions and mechanisms to build credibility, amongst a population accustomed to an arbitrary and partisan legal system, will be a long-term project.

7. THE DEVELOPMENT OF INTERNATIONAL INSTITUTIONS AND REGULATORY MECHANISMS

7.1 Conflict Between National Sovereignty and International Regulation

Proposals for supranational governance in any sphere have always attracted vociferous criticism, particularly from powerful states, on the grounds of national sovereignty. With the notable exception of the European Union, international bodies have not therefore been accorded the right by their members to propagate binding legal instruments. International organisations such as the United Nations and its subsidiaries can function in a particular field only with the continual agreement of the states involved, although the agreement of smaller members may be secured by the application of political pressure from their more powerful neighbours. Only through specific international treaties, which bind those who ratify them, can any form of international regulatory regime be established, and even then monitoring and enforcement can be problematic.

Opposition to an official and binding international dimension varies according to the issue in question, but has been particularly strong in the nuclear sphere due to its connection with national security. The culture of secrecy pervading the industry has largely precluded meaningful official reciprocal access to national nuclear facilities.[85] It has therefore prevented the development of an international regulatory regime despite continuous and widespread public distrust of the arrangements for industry scrutiny (Wynne 1996).

The considerable body of technical standards and guidelines developed by the IAEA and others, as discussed in Chapter 4, remains purely advisory. Political pressure may be applied in order to induce compliance, but governments are not legally bound to act in accordance with recommended practice. The EURATOM regime, in contrast, is 'hard law', requiring implementation and enforcement at the national level, and also limited regional access.[86] Even within Europe, however, there is a lack of consensus between member states on nuclear governance issues, and the perception that the EURATOM regime concerns itself only with the interests of nuclear states. Monitoring and enforcement provisions are limited, mostly to plutonium accounting, due to continuing influence of the national security factor. France in particular keeps its nuclear agenda as exclusive as possible (Liberatore 1996) and would veto any attempt to broaden the remit of binding international regulation.

[85] Although access was granted under the IAEA nuclear non-proliferation safeguards regime, it was by appointment only, and did not amount to unconstrained inspection.

[86] Allowing access to non-proliferation inspectors from a regional agency was a significant step for Europe, but was judged to be preferable to granting access to American inspectors as required under the bilateral agreements of the time. (Braithwaite unpublished).

There is, however, an increasing international dimension to the nuclear industry based on the perception that public acceptability hinges on the operating record of nuclear power globally. Therefore states which favour the use of nuclear power, or which merely wish to keep the nuclear option open in an uncertain world, and the externally aware segments of the industry itself feel the need to concern themselves with the operation of the technology in other countries. The resulting measures do not yet amount, even unofficially, to international regulation, and are not likely to for the foreseeable future, but they are nevertheless important in that they open extensive channels for communication and influence. Both top-down and bottom-up approaches have been initiated, by governments and by the industry respectively, the Nuclear Safety Convention representing the former and the developing WANO programmes the latter. In addition, the international nuclear liability regime may increasingly involve the insurance industry in an indirect role.

7.2 Nuclear Safety in International Law

Prior to 1986 there existed only an underdeveloped regime for the assignment of national liability in the event of trans-boundary damage which channelled limited liability to the operator, emphasising that safety was strictly a national concern. The underlying assumptions were apparently that the risk of a major accident was very low and that operator liability would provide a sufficient incentive to ensure that one did not occur. The Soviet Union and its client states were not signatories, hence no international claims could be pursued in relation to the extensive losses, measured in billions of dollars, attributable to Chernobyl. The scale of that accident, and the information subsequently revealed regarding the problems of the nuclear industry in the former eastern Bloc, led to a revision of the original risk assumptions and a different opinion as to the advisability of entrusting the future of nuclear power solely to national regulatory arrangements. The Nuclear Safety Convention, which came into force in 1996, is the first intergovernmental attempt to address the issue of nuclear safety directly.

It was assumed by many observers of the negotiating process that the Convention would address the issue of safety standards, perhaps by enshrining the substantial body of IAEA guidance in a binding treaty and thereby conferring upon it the force of law (De La Fayette 1993). To do so would, however, have resulted in the exclusion from the regime, for technical, economic and political reasons, of the very states around which the concern over safety centred.[87] The eventual compromise rested on the use of a hard law instrument, in order to convey an impression of sufficient *gravitas*, rendered soft law by virtue of its

[87] The variability in technology, of different ages as well as in different locations, was considerable. Standardisation would have been economically impossible, as would mass decommissioning and replacement. In any case, there was no agreement as to the requirements for safe operation or the degree of risk, and the

content, since it contained no firm or measurable commitments and no limitations upon the exercise of sovereign power.[88] The resulting Nuclear Safety Convention is a compendium of fundamental principles couched in general terms, such as 'sufficient number of qualified staff', for which there are no reference criteria because no mention is made of the existing body of guidance (Boustany 1998).

The Convention does not represent a supranational order in the nuclear sphere, and does not dictate detailed safety prescriptions in a technologically deterministic manner. Instead it stresses the importance of participants asking themselves certain questions regarding the principles upon which their own safety regime is based whilst providing a forum, through periodic peer review meetings, for the discussion of a range of priorities and practices. It raises the profile of the lessons learned from previous accidents, particularly those relating to the various manifestations of the human factor. The need for comprehensive nuclear legislation (Articles 4 and 7), and for effective, and independent, regulation at the national level (Article 8) is emphasised. The Convention insists that the safety of existing plants be evaluated, and plants with deficiencies incapable of remedy closed as soon as possible, although it concedes that the timing of the shut-down may legitimately be influenced by the national energy supply scenario and the predicted socio-economic impact (Article 6). Unfortunately, there is no financial mechanism for assisting the transitional states with the very substantial costs directly attributable to closure and decommissioning, despite recent international precedents from other treaty negotiations,[89] hence the prospects for closure, even of the least safe reactors, are not enhanced by the Convention.

The peer review process, involving as it will a confidential grouping of government representatives several steps removed from the industry itself, cannot be in a position to determine the real extent to which measures have been implemented or directly to influence conditions on the ground. It may, however, serve as a useful forum for the discussion of continually evolving regulatory practices, emphasising the role of political responsibility for setting societal priorities. If confidentiality breeds trust, as intended, discussions may become increasingly frank and realistic, and thereby potentially more effective in harmonising perceptions of safety. There is, however, no guarantee that this will be the case. In terms of its practical impact on safety, one would expect the infrequent application of political pressure from the top down to have little motivational effect on the industry unless the message is indeed

standards proposed were perceived by some as an instrument of Western hegemony. (Reyners 1996).

[88] Soft law provisions are interpreted by addressees as desirable long-term goals, in the achievement of which they are permitted discretion as to the timing and extent of implementation. There are no methods of enforcement or penalties for breach since no firm commitments are entered into. 'Soft law' is perhaps more accurately considered not as law but as part of the process of dispute settlement, allowing a continuation of negotiations through the definition of deliberately vague or ambiguous terms, the favourable interpretation of which may be used to claim compliance with the expectations contained in the instrument. (Birnie 1992; Boustany 1998).

[89] For instance, the Multilateral Fund associated with the Vienna Convention on the Ozone Layer.

taken on board by domestic politicians. If they are convinced of the safety case, they may exert a measure of influence through the legal system, but such an indirect process, important as it may become in the long term, should not be expected to bear fruit within the design-life of the plants currently causing concern.

7.3 The Prospects for Self-Regulation at the International Level

Elements of the industry, particularly those based in states where public scepticism or outright opposition to nuclear power are significant, appear increasingly to view their future in terms of the axiom of 'united we stand, divided we fall'. They are concerned that the performance of technology and actions of individuals in other countries, over which they have no control, will ultimately be used to judge the merits of their own continued existence. It is therefore perceived as a necessary survival strategy to emphasise the priority accorded to safety by their peers in other jurisdictions, independently of the official international framework.

The latter is regarded as an inherently long-term strategy which depends for its success on the effectiveness of governments in implementing their agendas and respect for national laws. In seeking to affect the behaviour of individuals via a chain of authority extending from government to legislature to regulator to plant manager and finally to operational staff, the official approach is insufficiently focused on the people whose actions ultimately matter. It is unlikely to result in a significant change of attitudes in less than a generation. The time horizon envisaged was clearly too distant to serve the immediate need for the industry to promote safety culture at plants with a remaining design-life of less than fifteen years. The response of the industry was the formation of WANO, as a means of directly influencing its target audience through communication, contact, exchange visits, and voluntary peer review. It has been an attempt to build a form of partnership, in contrast to the hierarchical official approach which has tended to patronise the states of the former Eastern Bloc. The result, according to those most intimately involved in the process, has been a significant change of attitude at most plants in the space of only a few years.[90] Many believe that, on balance, safety has improved, although this is debatable in states where the economic transition has been particularly severe and prolonged.[91] Nevertheless, it is agreed that the risk of an accident is much lower now that this form of intervention has been developed.

This private initiative suggests a concession by the more far-sighted elements of the industry that the

[90] CP Haigh, Head of European Support, Magnox Electric (personal communication)
[91] Richard Bye, UK Nuclear Installations Inspectorate (personal communication)

future of nuclear power depends on some form of regulation, in the broadest sense of the word,[92] to prevent accidents in all states using nuclear technology. The industry must then, out of self-interest, provide this service itself if public institutions, national and international, are not capable of so doing (Campbell 1988). This may, however, ascribe too great an element of conscious foresight to what has been an essentially incremental process developing in an *ad hoc* manner in response to concrete issues in specific locations. An alternative, and perhaps complementary, explanation is that the industry would like to forestall the encroachment on its freedom of action from additional official regulation by getting its own house in order, as quickly, and as far from the public gaze, as possible (Braithwaite unpublished).

The WANO regime is not presently intended to be self-regulatory. Its explicit purpose is to foster communication and co-operation within an industry which has traditionally been insular and secretive. The low priority accorded to safety and the concealment of operational information evident in the Soviet context were extreme, but criticisms of a similar nature, if not a similar extent, could be applied to the developmental stage of the industry in most nuclear states. Organised intra-industry communication in the West is a phenomenon of the last twenty years at most, and has really only become widespread in the last ten. It has been associated, in most advanced nuclear nations, with a significant decrease in incidents causally related to a lack of safety awareness. In some states, such as the USA, the regime has become explicitly, and powerfully, self-regulatory,[93] while in others it remains advisory.

In extending this network of communication worldwide, the industry has created the potential for self-regulation at the international level, which could, if seen to be effective, influence public opinion in such as way as to keep the nuclear option open for the future. At present WANO has universal subscription amongst utilities operating civilian nuclear reactors and is therefore in a unique position both in terms of the information to which it has access and the degree of insider credibility it can claim. It would be well placed to develop an effective *de facto* self-regulatory role should it choose to do so. It would, however, be unlikely to advertise such an intention for fear of alienating members and attracting attention to the safety issue, a factor which often appears to rebound on the industry whatever the actual content of the safety message.

[92] Regulation in the broader sense does not refer merely to formal legal mechanisms of control by public authorities, but to an organised means of harmonising standards and attitudes within the constraints imposed by context, whether or not the process has any official status or legal force.

[93] In the case of America, this may have been a private sector reaction to a highly prescriptive and inflexible form of public regulation which is widely perceived, by both the industry and its critics, to have failed, despite its carefully contrived complexity, to fulfil its role of balancing the interests of the industry and the public in a constructive manner. More information has always been available to the public, including to persistent and organised critics, in America than elsewhere, and this has been used very effectively by the anti-nuclear lobby to put pressure on the industry. (Rees 1994).

Where self-regulation is strong on a national level, as in the USA, it has tended to complement official regulation, although the balance of power between the two can be controversial. The official regulator may devolve certain responsibilities to the industrial body,[94] or may partially rely on privately collected statistical performance assessments (Rees 1994). However, private institutions such as the American INPO regard their information as confidential, and the public accessibility of the national regulatory process is therefore limited.[95] On an international scale, where there is no legally binding regulatory regime and institutional control is inevitably weak, the same complementary role, and the same criticism, could apply if the current WANO communication network should become visibly influential. There may be a need, as at the national level, to define the relationship between the public and private bodies for the sake of accountability and in the public interest.

If the official national regulatory process in some Eastern Bloc countries were to remain weak and they became reliant on international self-regulation, there would be a very real possibility that access to safety information would be unreasonably limited. The nuclear industry wishes to avoid public concern, but lack of information, or misinformation, is capable of causing considerably greater alarm in the long term as well as generating an extremely damaging lack of trust in both the industry and nascent public institutions. In order to be stable, and ultimately effective, a regulatory system must be seen to achieve legitimacy with both the industry and the public. It must not therefore constitute a technocracy operating without reference to public institutions and the public interest. To do so would be to replicate a fundamental error of the Soviet Union, and to an extent of the nuclear community generally, thereby laying the foundations for another crisis in the future.

7.4 The Potential Regulatory Role of the International Insurance Markets

The international liability regime, introduced in the Paris and Vienna Conventions of 1960 and 1963 respectively, has been under review since its inadequacy was exposed in the aftermath of Chernobyl. Its coverage, in terms of the number of signatories, was limited and the liability ceiling, $5 million under the Vienna Convention and $22 million under the Paris Convention, was revealed as derisory (Carroll 1996). In 1988 the Paris and Vienna Conventions were unified under a Joint Protocol in order to extend uniform treatment to all existing signatories, and a revision of the overall regime began. The newly independent states of Eastern Europe were encouraged to become parties to the process as soon as possible.

[94] As the NRC has done with INPO in relation to the development of operator training programmes.
[95] INPO statistics and reports voluntarily presented to the NRC are immune from cases under the Freedom of Information Act and therefore not publicly available. The regulatory process is increasingly felt to be

Liability is still to be channelled to the operator as before but the definition of damage is considerably broadened and the liability limit raised to approximately $400 million, with a requirement that operator seek insurance cover, or hold security, of that sum.[96] In practice, the limit reflects the maximum exposure the pooled nuclear insurance market is prepared to bear rather than the damage likely in the event of a serious nuclear accident (Layard 1996). The limit has been subject to legal challenge on the grounds that it seriously dilutes the incentive placed on the operator to act conservatively with regard to safety,[97] but has been upheld as sufficient in the interests of legal certainty and the continued commercial viability of the nuclear industry (Layard 1996; Sands 1996). If the extent of damage in all its forms was the basis for liability, then nuclear risks would be uninsurable.[98]

The introduction of much higher liability limits increases the incentive for insurance pools to assess, and seek to reduce, the risk to which they may be financially exposed.[99] Insurers, whose experience of nuclear plant is derived from reactors which have had a good safety record over several decades, have not been unduly concerned about nuclear risks.[100] If, however, they perceive, rightly or wrongly, that plants in other locations represent a greater risk, then they may wish to seek additional external measures of safety. It is possible therefore that they may compare the design of the plant with the available technical guidance from the IAEA and others, perhaps refusing to insure plants which did not meet the voluntary criteria. Being essentially risk averse, they may also appreciate the role of non-technical factors and seek evidence of relevant opinions on a wider front. Both technical and non-technical guidance could then become effectively mandatory.

If WANO were to decide, at some point in the future, to go beyond seeking to influence members through communication and to apply pressure upon a member felt to be threatening the future of the industry with its persistent disregard for safety, it is possible that the counter-threat of jeopardising that member's access to insurance could be the ultimate sanction. With its universal subscription, WANO is currently in a strong position since membership withdrawal would send a simple but powerful message to insurers. Without insurance, operation would probably not be feasible in the future under the agreed liability regime,[101] hence recalcitrant members could be privately pressurised into changing their

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insufficiently accountable for its decisions.

[96] The installation state can choose to shoulder a proportion of this amount itself, provided that at least $200 million is channelled to the operator. (Boulanenkov 1997).

[97] *Energy Probe et al v Attorney General of Canada* (1994) 17 OR (3rd) 717.

[98] A risk is uninsurable if there is no market for the insurance product at the premium required by the insurer to both reflect the risk and to make a profit. (Kunreuther 1997).

[99] The pooling system is currently able to make commitments in material damage property insurance and third party liability insurance combined of approximately $2 billion. (Sladonja 1997).

[100] Although the pools already employ specialists in risk analysis to assess the risks they cover (Sladonja 1997).

[101] As Braithwaite explains, 'Potentially, the international insurance industry has the power to stop what mass democracy could only wind back and state regulation could only risk-manage.' (Braithwaite unpublished).

behaviour. The threat of such a sanction could be enough to allow eventually for the development of real self-regulation at the international level, although it remains a distant, and highly speculative, prospect. It is not in tune with WANO's current inclusive approach, and if invoked would be a reflection of the ultimate limits of a purely advisory process.

7.5 Summary

- National security aspects of the nuclear field have precluded the development of binding regulatory mechanisms at the international level despite the magnitude and clear transboundary nature of the risk. Nevertheless, forms of international governance have begun to proliferate and already exert a considerable influence throughout the industry.
- The Nuclear Safety Convention, although cast as hard law, places no legally binding limits on the exercise of sovereignty. It is cast in general terms in order to gain broad subscription, and provides a forum for both the discussion of issues and the application of political pressure. It is sufficiently indirect that its effects can only be long-term in nature, particularly since there is no mechanism for financial assistance with decommissioning older reactor designs.
- The international communication network being fostered by WANO has considerable potential, and universal applicability, in the field of nuclear safety due to its credibility within the industry. Its approach, a safety culture message targeted at the industry, has already made a positive difference in the Eastern European region, whose problems had spurred its development within the last ten years. The trade-off between effectiveness and public accountability and control is an aspect requiring debate, particularly if the regime were to evolve into a form of self-regulation.
- The revision of the international liability regime, and especially the increase in the liability limit, should increase the incentive for insurers to control the risks to which they are exposed. Suggested standards set by the IAEA and others could become effectively mandatory if insurers require that they be met as a condition of cover.

8. THE NEGOTIATION OF AGREEMENTS ON NUCLEAR PLANT CLOSURE

8.1 The Role of Closure in the International Programme for Safety Improvement

The initial reaction of the international community to the problems of the Eastern European nuclear industry was encapsulated in the Lisbon Multilateral Nuclear Safety Initiative of 1992, which sought to achieve a balance between retrofitting safety measures, providing for investment in alternative generating capacity and energy efficiency and, ultimately, closure of the oldest and least safe plants (see Chapter 3). The process is not, however, unfolding in the manner envisaged only a few years ago. Specifically, the intervening years have not seen the permanent closure of a single unit, despite the central role closure was intended to play in the risk reduction strategy, nor has there been a serious investment programme for the provision of energy efficiency or alternative generation capacity.

Donors fear that even short-term safety upgrades are being seen by the host countries as a licence to continue operations, as closure timetables, upon which the funding for upgrades was supposedly dependent, are postponed (Pavlov 1998). They complain of extortion and mismanagement, and may conceivably begin to restrict future funding for safety improvements. This perception is unfortunately oversimplified, and complaints of this nature will do nothing to resolve the dilemma to the satisfaction of participants on either side of a widening gulf. Donors have hitherto failed to appreciate the scale of the obstacles to the retirement of nuclear generating capacity, which, despite its shortcomings, often comprises the newest and most reliable generating plant in the former Eastern Bloc.

8.2 The Energy Debt Crisis and Consequent Dependence on Nuclear Generating Capacity

With the exception of the Russian Federation, the simple ratio of installed nuclear capacity to total generating capacity in the countries of Eastern Europe and the FSU does not represent the extent of their reliance on nuclear power (Table 2). The Russian decision to phase out energy subsidies for its former client states has had a major impact on the economics of energy such that high fuel prices for ageing, unreliable and inefficient oil and gas plant have resulted in the accumulation of large energy debts. There is presumably a limit to Russian tolerance of this phenomenon, which could be enforced in some cases by cutting off supplies and in others, where a transit role to more distant markets would preclude such action, through broader use of Russia's considerable economic leverage. Hence there are political and economic pressures on the purchaser states to rely disproportionately on nuclear power rather than fossil fuels. With conventional generation often idle due to high fuel costs and large energy debt burdens, the nuclear plants have an important role in servicing as much demand as possible and in maintaining the integrity of the transmission system in order to avoid widespread and potentially prolonged power outages (Sich 1996). Maximising the use of nuclear power, as opposed to importing oil and gas from Russia, also allows the former client states a highly prized degree of independence.

Table 2: Installed Capacity and Nuclear Dependency. Per Cent

Country	*Nuclear Capacity*	*Nuclear Supply*						
		1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Armenia	23						37	
Bulgaria	31		32			46	42	46
Czech Republic	16		20			29	20	
Hungary	25		45			44	41	
Lithuania	42*	58	78	89	76	90	83	81
Russia	12**	12	12	13	11	12	13	13
Slovakia	32		53			49	45	
Ukraine	25+	27	29	33	34	37	44	45

* The capacity of the Ignalina plant was down-rated to 2500MW from 3000MW for safety reasons after the accident at Chernobyl. The figure here is based on the lower rating.
** Based on available capacity (1992) of 166 GW rather than nominal capacity of 213 GW.
+ This 1995 figure includes the 1000 MW Zaporizhzhya 6 which came on line only at the end of 1995 and explains the sudden increase in nuclear generation percentage from 1996.

Sources: Ebel - Energy Choices in the Near Abroad: The Haves and the Have Nots Face the Future; OECD - Electricity in European Economies in Transition; Nuclear Energy Institute - Source Book, 4th ed; Schlesinger - Nuclear Energy Safety Challenges in the Former Soviet Union; Core Issues 1998(2).

In addition to their reliance on existing nuclear capacity, national governments of nuclear states in the East are almost all planning to bring new nuclear generation on line early in the next century, and indeed some have done so already. Two new units have already come on line in the FSU,[102] with an additional sixteen planned for the Russian Federation,[103] two for Ukraine,[104] one for Belarus and one for Kazakhstan.[105] In Central Europe, the Czech Republic and Slovakia are both completing Soviet-era

[102] At Balakovo in the Russian Federation in 1992 and at the Zaporizhia plant in the Ukraine in 1996.
[103] Russia plans to commission 16 units by 2010, including 2 floating units, according to the 'Programme for Development of Atomic Energy in the Russian Federation in 1998–2005 and for the Period until 2010' which was approved by governmental decree No 815 on 21 July 1998. See http://www.bellona.no/e/russia/status/9809-1.htm for details.
[104] The Ukraine plans to complete a fourth unit at Rivne and a second at Khmelnitsky, either with Western or Russian assistance.
[105] Kazazhstan is planning to build a reactor at Lake Balkhash with Russian assistance. See *East European Energy Report* (1998). Kazakhstan sees nuclear power plant going ahead. 84(Sept): 18.

plants with Western assistance.[106] Even Bulgaria has proposed completing a plant at Belene, but finance for the project is likely to be very difficult to attract.

8.3 The Relativity of Risk Perception

Western engineering safety standards are devised to include considerable theoretical safety margins through the concept of defence-in-depth and are thus meant to be strongly precautionary as required by the public. Nuclear power is not generally perceived by the Western public as a matter of necessity since energy from other sources is readily available, hence the implicit risk-benefit calculation requires the risk to be strictly minimised where the benefit is perceived to be marginal. Precaution is, however, expensive.

The situation in the East is very different, despite the legacy of Chernobyl. In the immediate aftermath of the accident most nuclear programmes were cancelled, halting construction on many plants nearing completion. However, the economic privations of the transition period, including much less reliable power supplies in many areas, have shifted priorities. Nuclear power is increasingly perceived as a necessity, particularly by governments and industry in countries not well endowed with oil and gas reserves. Moratoriums have generally been lifted.

Risk perception by the public in the former Eastern Bloc is more complex than that of their governments, the debate being far from academic in this context and the issues on both sides therefore focused by personal experience. Opponents of nuclear power argue that their governments deny them access to information and frustrate their attempts to put their case to their compatriots,[107] which is certainly a credible complaint given the political culture from which the former Eastern Bloc is emerging.[108] However, public concern over nuclear safety does appear to have been largely overshadowed by immediate economic priorities, including domestic electricity supply and supplies to industry upon which their continued employment, and other benefits, may depend (Pavlov 1998).

People oppose the old energy dependency on Russia as a risk factor compromising their new-found political independence, but equally may resist Western paternalism and the forward march of a market system which many blame for their current economic problems. A substantial proportion of the public therefore also appears to regard indigenous energy supply as an important means of protecting an

[106] Temelin, in the Czech Republic, has been controversial for reasons of cost and schedule, while Mochovce, in Slovakia, has commenced operations despite vehement protests from neighbouring Austria.
[107] For instance the Czech branch of Friends of the Earth, Hnuti DUHA, has repeatedly made such allegations in relation to the completion of the Soviet-era Temelin plant which they oppose.
[108] Where civil society remains underdeveloped, and there is no tradition of public consultation or democratic accountability, it may be tempting to obstruct the organisation of political opposition in order to claim that none exists.

independent identity. For countries without a natural resource base in hydrocarbons, nuclear power is often perceived by the citizenry as indispensable, either as a positive emblem of national modernity or as a necessary evil.

8.4 Local Specialisation and Social Dependency

It is typical for nuclear plants in the FSU to co-exist with a town purpose-built for the plant's workforce and their families.[109] The social infrastructure of these towns[110] and the welfare of all the inhabitants, whether employed at the nuclear facility or not, would traditionally have been the responsibility of the local branch of the ministry which ran the plant. Nuclear plants were not alone in having such responsibilities under the Soviet system which allocated specialities to each locality through the central plan. Soviet enterprises existed in order to fulfil dual social roles, contributing perhaps a single very specific product to the region or to the Union as a whole and providing for general resource management and distribution at a local level. Thus the enterprise and the locality could not be meaningfully distinguished from each other.[111]

The degree of local specialisation inherited from the USSR, combined with the legacy of chronic housing shortage, has resulted in considerable labour market inflexibility. Alternative employment within the same locality can be very difficult to find, but moving to another region in search of employment is also problematic if housing is not available. Within a particular locality workers are generally dependent on the continued goodwill of their employer as provider of housing and social services, and therefore often have no choice but to continue to work despite persistent non-payment of wages. Wage arrears for the economy as a whole reached an estimated £10 billion by the end of 1997 according to the State Statistics Committee.[112] An enterprise wishing to dismiss a redundant worker would be legally required to make a redundancy payment, hence workers are commonly kept on the official payroll, and tied to their nominal employer, with no prospect of pay or redundancy (Standing 1996).

The new Russian capitalists have sought to shed social responsibilities wherever possible, but capitalism has not yet penetrated the electricity sector. With the old monolithic system largely still in place, albeit crippled by non-payment of debts by all parties, the old social responsibilities remain, but without the means to pay for them. The infrastructure and services cannot alternatively be provided for by the

[109] According to Minatom, there are currently 120 such towns across Russia.
[110] This would include housing, nurseries, schools, shops, roads, hospitals, clinics, sanatoria, gymnasiums, stadiums, swimming pools, holiday camps and a dedicated food and agricultural complex. See http://www.ai.x-atom.net/minatom/activity.html.
[111] This is especially true in the case of the erstwhile closed cities in the Urals which were originally part of the Soviet military-industrial complex.
[112] For the December 1998 figures see http://www.icem.org/campaigns/no_pay_cc/situation_update_9712.html.

government, as they are in the West, in the absence of substantial tax revenues. The goal of ultimately retaining the plant, as the only means of avoiding extreme social dislocation, is seen as being of overriding importance. It is almost universally perceived that money spent on upgrading a plant which was subsequently closed would have been wasted, and waste on such a scale is a luxury which cannot be afforded. The response, rational in the circumstances, is to regard the investment as a unique opportunity to postpone hard decisions on social restructuring. Indeed, the increased margin of safety may even be perceived as sufficient to permit a reduction of domestic investment in the plant in order to concentrate resources on social infrastructure or wages.

8.5 Governance and Investment in the Electricity Sector

The weakening of legitimate central authority which has taken place during the period of economic and political transition has led to a crisis of governance, particularly in the FSU, and therefore to large financial risks for both foreign and domestic investors. Widespread corruption (EBRD 1997) crime (Handelman 1995) and legal unpredictability (Jensen 1998; Ledeneva 1998) have therefore resulted in capital flight on a grand scale, and funds provided as grants and loans by foreign governments cannot hope to fill the huge gap.[113] Investment in basic infrastructure is not consistent with high risk since it requires that large amounts of capital be sunk into fixed assets from which one might expect only moderate returns in the long term. It therefore requires confidence in economic, political and legal stability (EBRD 1997). Only if it becomes clear that Russians themselves have sufficient confidence in their state to invest in domestic infrastructure would it be likely that private foreign investors would also be interested (Gregory 1998).

Existing fossil fuel generating capacity, much of which is in any case approaching the end of its life-span, is currently deteriorating rapidly through lack of investment in maintenance. What is now a surplus of generating capacity, with dependence on nuclear plants largely due to lack of funds to purchase fuel, could quickly become a shortage of capacity in the absence of such investment. With governments choosing to address this issue by allocating their scarce resources to the completion of Soviet-era reactors, dependence on nuclear power could become institutionalised unless private investors can be induced to invest in non-nuclear capacity. Investment in energy efficiency improvements, for which there is considerable scope,[114] could relieve the pressure on the older reactors, perhaps allowing some closures,

[113] For instance, according to the Economic Commission for Europe, in 1992–94 gross foreign and domestic investment in Russia was estimated at $3.9 billion and official grants and credits totalled $15.5 billion, while capital flight was estimated by the Russian bureau of Interpol at $80 billion by the end of 1994. (Wesolowsky 1998).

[114] In Russia it has been estimated that energy savings of 10–15% across the whole economy would be possible rapidly and at minimal cost, and that longer-term cost-effective investment could produce savings of an additional 30%. The intensity of energy use is between two and three times higher in Central Europe and the

but this is also suffering from the financial drain.

Restructuring of the energy sector, in order to establish an institutional framework for private investment, is a difficult and costly proposition, constituting a significant challenge to the traditional approach. The political culture in which much of the ruling class of the former Eastern Bloc is still largely steeped remains biased against a proliferation of small-scale private generators and investments in energy efficiency. Large-scale supply projects like the new generation of nuclear plants, which are by nature highly centralised and well understood, constitute a much clearer and simpler focus for both government investment and control than do small decentralised projects.[115] Energy efficiency, in particular, is the culmination of millions of separate investment decisions which may occur once some form of stability has been restored, but are not subject to central control and cannot therefore be planned. The concept of limiting the role of the political centre in this strategic area to one of merely facilitating private investment decisions is one which Russia in particular is likely to find alien.

8.6 Nuclear Reactors as Bargaining Chips in the Quest for Economic Development

As the prospect of achieving the early closure of whole classes of plant has receded, the prime target for closure is Chernobyl, at which one reactor remains operational.[116] At the December 1995 meeting of the G-7, a Memorandum of Understanding (MOU) was agreed with the Ukraine on the final closure of Chernobyl by the year 2000 in exchange for Western assistance with the decommissioning of Chernobyl, nuclear safety improvements at other Ukrainian reactors, long-term stabilisation of the sarcophagus, support for energy investment plans, reform of the Ukrainian energy sector and social restructuring.[117] The social aspect appears to have been quietly dropped and the major sticking points have been the financial proposals for the sarcophagus and the nature of the energy investment plans. Arguments over funding for the sarcophagus are unsurprising given the fact that it involves the commitment of a very

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FSU than in developed Western countries, largely due to the preponderance of heavy industry such as metallurgy, petrochemicals and construction. Heavy industry accounts for an average of 50% of Russian electricity demand, although in some regions the figure can be as high as 70%. The comparable statistic for the OECD, where the proportion of light industry and services is much higher, is 35%. At least 35–40% of industrial electricity use is estimated to be wasteful. In terms of output per unit of energy consumed, Russia is only
one-sixth as efficient as Japan and one-third as efficient as the United States. See Russia's Energy Efficient Future: A Regional Approach. Proceedings of an IEA Conference, Chelyabinsk, Russian Federation, September 1996.

[115] *Ibid*, p77.

[116] The accident destroyed Unit 4 while Units 1 and 2 would require extensive repairs before they could be brought back on line, the latter due to a fire in the turbine hall in 1991. Unit 3, which is connected to the sarcophagus surrounding the remains of Unit 4, has been upgraded and is operational, despite the possibility that a structural failure of the unsound sarcophagus could have serious implications for its own integrity. (US DoE 1997).

[117] The burden of fulfilling social obligations to the more than twenty thousand residents of Slavutich, the town built to replace Pripyat after the 1986 accident, rests largely on the continued operation of the remaining Unit 3.

large sum of money with no return on investment. The investment dispute centres around the nature of new generating capacity, specifically whether or not it should also be nuclear.

The MOU agreement involved a commitment to the completion of two partially constructed Soviet-era reactors at the Khmelnitsky and Rivne plants, apparently at the behest of Western governments under pressure to secure contracts for their own nuclear industry.[118] However, the EBRD, which was supposed to provide funding under the agreement, can only lend where the least-cost criterion has been satisfied. An independent assessment held that the investment would not be economic, on the grounds that the Ukraine is short of funds to purchase fuel for its existing generating capacity rather than being short of capacity *per se* (Surrey 1997) although a later study undertaken by consultants with connections to the nuclear industry altered many of the assumptions and, somewhat tentatively, reached the opposite conclusion.[119] The economic position is in a sense irrelevant since the original decision was made on political grounds, but it has been a considerable embarrassment, particularly for the EBRD, for the dichotomy to have been so publicly exposed. The Ukraine, having been promised new reactors, is now unwilling to compromise and may seek Russian assistance if Western funding is not forthcoming.

The Ukraine had initially set the total cost of closing Chernobyl at £12 billion, but dropped its estimate to £4.5 billion and eventually settled for about £2.5 billion in grants and loan pledges under the MOU (Ebel 1997). The process of raising the money has been protracted, to the point where it would not now be possible to complete replacement capacity by the deadline, hence closure will be postponed. The Ukraine is attempting to concentrate Western minds by suggesting that, in addition to retaining the currently operational unit for another 10–15 years, another two units may have to be repaired and brought back on line if the financial commitments made under the agreement are not adhered to (Thomas 1998).

The high profile political battle of wills over Chernobyl represents the recognition by the West of its own inability to impose its views on nuclear states in the East and the determination of those states to apply what leverage they can in securing assistance for intractable problems. The Eastern states enduring the bewildering upheaval of economic transition understand that there will be no new Marshall plan for the redevelopment of the former Eastern Bloc. They must achieve development by their own efforts and they will be handicapped by the legacy of central planning, which will ensure that in many ways they begin the process from a position of considerable disadvantage. They also know the importance placed by the West on the nuclear issue, initially with regard to nuclear weapons arsenals and latterly regarding nuclear power plants which do not meet international standards (Zyla 1997). The golden opportunity to extract the highest possible price for what have become, in this sense, their most valuable assets, is obvious.

[118] See for instance *Energy Economist* (1998). K2R4: Cutting the Gordian knot. 201(July): 7.

Donor states complain of extortion, but the situation is arguably not so clear. The complex role of nuclear power in the economies and societies of the former Eastern Bloc is not generally appreciated, nor is its connection with national pride in the face of a perceived Western corporate take-over. Western governments do not understand the resentment felt in countries such as Ukraine which, despite poverty, has been left to cope with the on-going consequences of the Chernobyl accident for which it was not primarily responsible. It should come as no surprise that these states might exploit their only powerful point of leverage in seeking a burden-sharing arrangement, and indeed such an arrangement might be considered equitable. The issue of accountability in the use of donated funds is, however, a legitimate concern in view of evidence that some funds may have been diverted. Maintaining tight control over funds committed for a specific purpose will be vital if the process is to be credible.

The deciding factor facing the Ukraine in the game of brinkmanship is likely to be the urgent need for funds to construct a new sarcophagus to contain the remains of Chernobyl Unit 4. The current structure was built quickly and under extremely hazardous conditions, and its constituent materials have since been degraded by continuous exposure to very high levels of radiation. It is therefore unsurprising that it should now be structurally unsound.[120] The need to fund the permanent containment of an estimated 34 metric tonnes of radioactive dust particles from the decomposing fuel masses, material which would seriously aggravate existing contamination levels if released through structural collapse, is ultimately likely to force the Ukraine to close Chernobyl.

There is however, no similarly acute point of leverage which could be used to force the closure of other plants across the former Eastern Bloc. Offers of eventual membership of the EU are being used to apply pressure for closure on states operating VVER 440-230s, but the RBMKs, virtually all of which are located in Russia itself, are not equally susceptible to such tactics, despite posing arguably the larger risk. If Western governments wish to achieve the permanent closure of these plants then they will have to do so in constructive political and financial partnership with a Russian government they appear so far to have made little effort to understand.

8.7 Summary

- Closure of older plants, as envisaged under the Lisbon Initiative appears increasingly unlikely in the short term.

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[119] *Financial Times* 04/04/98, p2.

[120] It has an estimated 1500 meters of cracks and is known to leak, allowing the ingress of rainwater. A neutron flux sustained for several hours, and a concomitant increase in radiation levels, has recently been observed on

- High fossil fuel prices have led to dependency on nuclear generating capacity throughout the former Eastern Bloc, and this dependency will be increased if current government spending plans for new nuclear plants are adhered to as a means of achieving energy independence.
- Risk must be treated as subjective, and therefore relative, rather than objective and universal. States and their populations need to arrive at a balance between estimates of risk and benefit that is appropriate for their circumstances. Outsiders who disagree cannot expect to impose their own views.
- The Soviet legacy of local specialisation and social dependency on industrial concerns presents an additional barrier to closure due to the huge costs of social restructuring.
- The crisis of governance and consequent capital flight have hindered vital investment in the electricity sector, reducing the range of options for electricity supply.
- The bargaining process, illustrated by the game of brinkmanship over the closure of Chernobyl, is being approached in a fundamentally unconstructive manner.

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several occasions.

CONCLUSIONS

International intervention in the nuclear industry of the former Eastern Bloc has now been underway for nearly a decade, sufficient time to draw preliminary conclusions as to the effectiveness of the various international programmes and the validity of their underlying assumptions. There have undeniably been considerable achievements in nuclear safety. A vast improvement in communication within the industry has increased accident awareness, while repairs and physical upgrades have been widely undertaken. However, several fundamental assumptions as to the nature of safety and the means of achieving it have proven to be unduly simplistic, leading to significant disparity between the scope of the problem and that of the proposed solutions. The debate is germane not only to the Eastern European case study, although that has been the focus of attention in recent years, but generally within a nuclear industry which has yet to control its externalities in such as manner as to achieve popular legitimacy. If it is to do so in the future then the following assumptions must be challenged:

Assumption 1: Risk and safety are firmly rooted in the technology of the engineered system and can be meaningfully quantified in an objective manner.

The attitude that risk is primarily a function of the technology in use has been discredited since the investigations of Three Mile Island and Chernobyl, which emphasised the importance of the human factor and indicted the institutional framework for nuclear governance. One clearly cannot estimate risk in a meaningful way without taking account of these crucial factors, or of the context of political and economic instability prevailing during the transition period, yet these aspects are excluded from the analysis since their impact cannot be quantified.

By defining the problem solely in technological terms, conventional risk analysis undervalues non-technological solutions, such as an emphasis on safety culture, which would be much less expensive and probably more effective. With insufficient attention to human factors, costly technical interventions could fail to deliver risk reduction, whereas in appropriate combination the effects would be complementary. Indeed, where design safety margins are relatively thin, the actions of individuals and their accountability for those actions are particularly important.

Assumption 2: Risk acceptability, or unacceptability, can be determined independently of the social, economic and political context.

Relative stability and prosperity have allowed the community of Western nuclear states the luxury of being able to take a detached long-term view of the nuclear dilemma in the former Soviet empire. The initial intervention plan therefore favoured the extensive upgrading of only the latest generation of Soviet-era reactors, while assuming that earlier models, which could not be upgraded to meet international technological standards for defence-in-depth, would be phased out by their host states at the earliest opportunity. This approach fails, however, to recognise that the perceived acceptability of a given risk is dependent on comparison with the available alternatives, in other words, risk is relative rather than objective. Where the alternative may be the loss of the most reliable and affordable source of electric power, the risk of operating without layers of technological redundancy is judged to be acceptable.

The economics of transition has meant that reliance on existing nuclear plants is substantial and increasing, hence closure, even of the least safe facilities, has been impossible. This disparity between the original proposals and current economic reality must be recognised and addressed through a shift in the focus of the intervention programme towards increasing the safety of all plants rather than primarily addressing theoretical risks at the most modern facilities. Given the expense of the technological approach and the limited international funding available, upgrading most plants to international standards would not be feasible. It becomes, therefore, increasingly important to consider addressing non-technological aspects of risk which have the potential to provide generalised safety improvements.

Assumption 3: Solutions to serious nuclear safety problems are best defined and implemented by nuclear experts.

The most fundamental flaw of the Soviet nuclear industry was that of unaccountable governance by insiders with a vested interest in the future of nuclear power, a situation which the international intervention programme is in danger of replicating. Western nuclear contractors, whose domestic business has been rapidly diminishing, have been heavily involved in the process of assessing and addressing nuclear risks in the former Eastern Bloc as part of their strategy for seeking new markets. It is in their interests to recommend extensive upgrading, or the construction of replacement nuclear capacity, despite the enormous cost. International nuclear organisations also generally retain an outdated promotional role in addition to their governance functions.

Experts clearly have a vital role to play. WANO measures to strengthen safety culture from the bottom up, in order to ensure that all actions taken are conservative with regard to safety, are likely to be particularly valuable in the short term since they exert their effects directly upon the individuals whose actions actually matter. However, the considerable influence of the industry over the agenda for the spending of public money must be carefully scrutinised. Insiders must be accountable to legitimate public authority and should not be given responsibility for determining what is in the public interest. The potential effectiveness of WANO cannot therefore allow it to substitute in any country for effective national regulation in the long term.

Assumption 4: National regulatory reform can effectively address the safety issues associated with the Soviet-era reactors.

State regulation is a top down activity, inherently less direct in its impact than the WANO system of risk communication and peer-review. Regulatory reform, even undertaken in the context of stability, is therefore unlikely to be effective in the short term. The realisation of potential benefits from the reform of an opaque and entrenched system such as prevailed in the Soviet Union can be expected to be an even more protracted process, particularly in the absence of adequate funding for enforcement. Expectations for the process of regulatory reform in some transitional states are therefore unrealistic. However, regulation is the necessary means by which competing priorities may be balanced in the long term, providing, in theory, a mechanism for the realisation of benefits in a context of contained externalities. It will not have a dramatic impact on the current generation of Soviet-era reactors, but its current development may lay the foundations for future control of the nuclear industry in the public interest.

Assumption 5: Nuclear safety is primarily a national issue.

The nuclear safety programme in the former Eastern Bloc has added considerable impetus to the *de facto* internationalisation of concerns about the nuclear sector, which began with Chernobyl. The formal position based in international law does not reflect this, due to the close connection of the nuclear industry with national sovereignty and national security, but there is nevertheless a developing recognition that compartmentalisation on a national basis has failed to deliver an acceptable and consistent level of safety. An optimistic view would suggest that the developing network of international risk communication, at the level of IASA, of governments and of the industry itself, may eventually have the effect of harmonising national nuclear governance. This could conceivably facilitate the evolution of a stable and credible risk-benefit consensus, if resources are not unduly limited and, critically, if the public interest is given sufficient priority. Without such a consensus, internationally agreed although nationally implemented, it is difficult to foresee the nuclear industry achieving the generalised public legitimacy it needs in order to have a future.

It is clear that the nuclear sector has, in addressing the aftermath of the Soviet collapse, faced its most formidable challenge to date. The industry and its Western state sponsors have been politically obliged to intervene quickly to address safety concerns abroad at a time when they have not yet achieved consensus on many of the issues they face at home. Nuclear insiders are convinced that the industry is safer than ever before, and evidence from performance indicators generally supports this view, but with minimal public participation in the process of defining safety and setting standards, the industry has yet to achieve popular legitimacy within its own national constituencies. The nuclear governance challenge is therefore far from unique to the former Eastern Bloc.

Eastern Europe has had the misfortune to suffer the consequences of both political extremes in quick succession, with inevitable detrimental effect upon the nuclear industry as on society as a whole. It has abruptly become the testing ground for the whole range of nuclear safety initiatives and is therefore an inherently valuable case study. However, the lessons which are emerging from the Eastern European experience will be of universal applicability. If nuclear power is to be a viable global option in the future, it must be firmly controlled in terms of its operation and its externalities, a feat which no nation can yet claim to have achieved. The words of Andrei Sakharov in 1989 in relation to Chernobyl are equally applicable today to the broader nuclear governance debate:

> These issues are so crucial that they cannot be left to technical experts, and still less to bureaucrats, whose approach is too narrowly technical, too tendentious and sometimes prejudiced, as it is paralysed by a network of mutual solidarity. *Glasnost* must apply to every aspect of the Chernobyl disaster; its causes and consequences. The absolute truth must be known. Everyone must be able to form an opinion about a matter which vitally affects our lives and our health, as well as the health of our offspring. Everyone must be entitled to take part in the adoption of decisions that will determine the future of our country and of the world.

Appendix 1 - Soviet-Designed Reactors in Central and Eastern Europe and the FSU

Reactor Units by Country

	Design	Number of Units	Commissioning Dates	Units Operational
Armenia				
Medsamor	VVER		1 - 1976	no
	440/230	2	2 - 1979	yes
Bulgaria				
Kozlodui	VVER		1 - 1974	yes
	440/230	4	2 - 1975	yes
			3 - 1981	yes
			4 - 1982	yes
	VVER		5 - 1988	yes
	1000	2	6 - 1993	yes
Czech Republic				
Dukovany	VVER		1 - 1985	yes
	440/213	4	2 - 1986	yes
			3 - 1987	yes
			4 - 1987	yes
Temelin	VVER		1 - (1999)	no
	1000	2	2 - (2000)	no
Hungary				
Paks	VVER		1 - 1983	yes
	440/213	4	2 - 1984	yes
			3 - 1986	yes
			4 - 1987	yes
Lithuania				
Ignalina	RBMK		1 - 1983	yes
	1500	2	2 - 1987	yes
Russian Federation				
Balakovo	VVER		1 - 1986	yes
	1000	4	2 - 1988	yes
			3 - 1989	yes
			4 - 1993	yes
Bilibino	LWGR	4	1 - 1974	yes
			2 - 1974	yes
			3 - 1975	yes
			4 - 1976	yes
Byeloyarsk	BN 600	1	1 - 1981	yes
Kalinin	VVER		1 - 1985	yes
	1000	2	2 - 1987	yes
Kola	VVER		1 - 1973	yes

	440/230	2	2 - 1975	yes
	VVER 440/213	2	3 - 1982 4 - 1984	yes yes
Kursk	RBMK 1000	4	1 - 1977 2 - 1979 3 - 1984 4 - 1986	yes yes yes yes
Leningrad	RBMK 1000	4	1 - 1974 2 - 1976 3 - 1980 4 - 1981	yes yes yes yes
Smolensk	RBMK 1000	3	1 - 1983 2 - 1985 3 - 1990	yes yes yes
Slovakia				
Bohunice	VVER 440/230	2	1 - 1981 2 - 1981	yes yes
	VVER 440/213	2	3 - 1985 4 - 1985	yes yes
Mochovce	VVER 1000	2	1 - 1998 2 - (1999)	yes no
Ukraine				
Chernobyl	RBMK 1000	4	1 - 1978 2 - 1979 3 - 1982 4 - 1984	no no yes no
Khmelnitsky	VVER 1000	1	1 - 1988	yes
Rovno	VVER 1000	3	1 - 1981 2 - 1982 3 - 1987	yes yes yes
South Ukraine	VVER 1000	3	1 - 1983 2 - 1985 3 - 1989	yes yes yes
Zaporizhia	VVER 1000	6	1 - 1985 2 - 1985 3 - 1987 4 - 1988 5 - 1989 6 - 1995	yes yes yes yes yes yes

Source: NEI (1997). Source Book, 5th ed. Soviet-Designed Nuclear Power Plants in Russia, Ukraine, Lithuania, Armenia, the Czech Republic, the Slovak Republic, Hungary and Bulgaria.

Appendix 2 - Technical Assessments

INSAG Critical Deficiencies and the RBMK and VVER 440/230 Reactors

Critical Deficiency	*RBMK*	*VVER 440/230*
Any situation in which accidents of the original design basis would not be coped with adequately	No design basis accident	No design basis accident
Deficiencies that could lead to failures that would not be coped with adequately, such as major deficiencies in the primary pressure boundary leading to an accident beyond the design basis		Critical weakness of pressure vessel welds
Unstable core behaviour or other events that could lead to a severe power excursion and inadequate shutdown capability in the short or long term	Unstable core, positive void coefficient, slow shutdown	
Inadequate shutdown capability or inadequate decay heat removal during any plant operational modes, including outages and abnormal events such as fire, flooding or complete loss of electrical power	Vulnerable to loss of coolant accident or loss of electrical power	Vulnerable to common mode failures, little redundancy
Inadequate containment or confinement capability such that credible failures or sequences of failures that cannot reasonably be excluded on probabilistic or deterministic grounds could give rise to a large external release requiring significant emergency measures	No containment	Inadequate containment

Source: International Nuclear Safety Advisory Group (1995). A Common Basis for Judging the Safety of Nuclear Power Plants Built to Earlier Standards. INSAG 8.

IAEA Safety Assessment Missions in Central and Eastern Europe and the FSU

	Pre-OSART	*OSART*	*ASSET*	*Safety Review*
Bulgaria				
Kozlodui		1990, 1991, 1998	1990, 1992, 1993, 1994, 1997	1995, 1996
Belene	1990			
Czech Republic				
Dukovany		1989, 1990, 1991	1993, 1996	1995
Temelin	1990, 1998	1992		1996
Hungary				
Paks		1988, 1991	1992, 1995	
Lithuania				
Ignalina		1995, 1997	1989, 1993	
Russian Federation				
Balakovo			1992, 1994, 1997	
Byeloyarsk				
Kalinin			1994, 1998	
Kola			1991, 1993	1991
Kursk			1992, 1995	
Leningrad			1993, 1996	
Novovoronezh			1991, 1993, 1998	1991, 1993, 1997
Smolensk			1993, 1997	
Slovakia				
Bohunice		1996, 1998	1990, 1993	1991, 1992
Mochovce	1993			
Ukraine				
Chernobyl			1992, 1998	1994
Khmelnitsky		1995, 1998	1993, 1997	1996
Rovno		1988	1993, 1997	1995
South Ukraine		1996	1995, 1998	
Zaporizhia			1994	1994

Source: NEI (1997). Source Book, 5th ed. Soviet-Designed Nuclear Power Plants in Russia, Ukraine, Lithuania, Armenia, the Czech Republic, the Slovak Republic, Hungary and Bulgaria.

Sample ASSET Results and the International Nuclear Event Scale (Levels 0-7)

	Years Assessed	*Total Reported Incidents*	*Level 0*	*Level 1*	*Level 2*	*Level 3-7*
Armenia						
Medsamor						
Bulgaria						
Kozloduy	1990-1993	93	59	14	0	0
Czech Republic						
Dukovany	1988-1993	476	363	19	1	0
Hungary						
Paks	1992-1994	160	125	6	0	0
Lithuania						
Ignalina	1989-1992	173	127	14	3	0
Russian Federation						
Balakovo	1992-1994	215	99	4	0	0
Kalinin	1984-1994	221	122	9	2	0
Kola						
Kursk	1977-1992	153	0	21	0	0
Leningrad	1982-1993	327	144	7	2	0
Novovoronezh						
Smolensk	1983-1993	316	150	16	2	0
Slovakia						
Bohunice	1990-1993	223	92	10	0	0
Ukraine						
Chernobyl	1989-1993	243	96	12	2	0
Khmelnitsky	1988-1993	221	72	16	1	0
Rovno	1988-1993	191	109	6	2	0
South Ukraine	1989-1994	178	92	6	0	0
Zaporizhia	1990-1994	709	251	15	9	0

Source: NEI (1997). Source Book, 5th ed. Soviet-Designed Nuclear Power Plants in Russia, Ukraine, Lithuania, Armenia, the Czech Republic, the Slovak Republic, Hungary and Bulgaria.

Appendix 3 - Legal Instruments

National Legal Instruments in Force in Central and Eastern Europe and the Former Soviet Union

Country	*Date (Revised)*	*National Law*
Armenia		No national legislation
Bulgaria	1985 (1995)	Act on the Use of Atomic Energy for Peaceful Purposes
Czech Republic	1997	Act on the Peaceful Uses of Nuclear Energy and Ionising Radiation and on Alteration and Amendments of Related Legislation (Coll. 18/1997)
Hungary	1996	Atomic Energy Act (No. CXVI)
Lithuania	1996	Law on Nuclear Energy (No. I 1613)
Romania	1996	Law on the Safe Conduct of Nuclear Activities (Law No. 111/1996)
Russian Federation	1995	Federal Law on the Use of Atomic Energy
Slovak Republic	1984	State Supervision of the Safety of Nuclear Installations (Act No. 28/1984)
	1993	Act No. 2/1993 on the Competence of the Nuclear Regulatory Authority
Slovenia	1984	Law on Radiation Protection and the Safe Use of Nuclear Energy
Ukraine	1995	Law of the Ukraine on the Uses of Nuclear Energy and Radiation Safety (No. 40/95)

Source: Nuclear Law Bulletin, OECD.

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