LIMITING FUTURE PROLIFERATION AND SECURITY RISKS

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PROLIFERATION DANGERS OF REPROCESSING

- The risks of reprocessing today are already unmanageable
  - Production and utilization of plutonium are not in balance, leading to growing stockpiles around the world
  - Material accountancy goals (timely detection of the diversion of 8 kilograms of plutonium) cannot be met at bulk-handling plants, in spite of allocation of significant inspection resources
  - Complementary measures like containment and surveillance do not fully compensate for inadequate material accountancy
  - Physical protection systems do not provide adequate assurance against current and anticipated future threats, yet industry continues to fight increases in security requirements – and in some cases presses for reductions – for cost reasons

WHAT THE U.S. CAN DO

- Elimination of reprocessing would greatly reduce resource burdens on international and domestic safeguards and reduce proliferation and terrorism risks
- The U.S. could help to discourage reprocessing around the world by
  – Getting the domestic geologic repository program back on track and demonstrating the technical and political feasibility of direct disposal of spent fuel
  – Ensuring that domestic requirements for securing weapon-usable materials are set at the highest levels and based on conservative assessments of current and future threats
  – Being realistic about the low potential for technological innovation to significantly increase the “proliferation resistance” of reprocessing or the accuracy of material accountancy methods at bulk-handing facilities
  – Using its bilateral nuclear cooperation authority more effectively

FAILURES OF MATERIAL ACCOUNTANCY

- IAEA: "Nuclear material accountancy remains a safeguards measure of fundamental importance"
- Over the last 15 years, numerous examples of failures of material accountancy to achieve timely detection and resolution of anomalies have come to light, involving large amounts of "material unaccounted for" that remained unresolved for months, years or decades
  - Plutonium Fuel Production Facility (Japan): 70 kilograms Pu: years
  - Tokai Reprocessing Plant (Japan): 206 kilograms Pu: decades
  - THORP Reprocessing Plant (U.K.): 190 kilograms Pu: months
  - Cadarache MOX Plant (France): 39 kilograms Pu?: years to decades
- These examples illustrate fundamental problems at bulk-handling facilities that prevent accurate and timely material accountancy:
  - residual holdup in process equipment
  - accumulation of scrap and waste in hard-to-assay forms
  - inaccuracies in material estimates
  - operator complacency/incompetence

IAEA GOALS CANNOT BE MET EVEN FOR NEW PLANTS

- The minimum loss of nuclear material which can be expected to be detected by material accountancy is given by

$$\mathbf{E = 3.29\ \sigma\ A}$$

  - σ is the measurement uncertainty of inputs and outputs
  - A is the plutonium throughput between physical inventories
  - Corresponds to a 95% confidence level and 5% false alarm rate
- Example: Rokkasho Reprocessing Plant (RRP)
  - Safeguards approach took 15 years to develop; requires 15% of IAEA inspection resources
  - Annual throughput: 800 t spent fuel, approx. 7.2 t Pu

    σ = ± 0.8% “expected” for Rokkasho

    E = 190 kilograms of plutonium
  - This means that a diversion would have to exceed about 25 bombs’ worth of plutonium before one could conclude with 95% confidence that a diversion had occurred
- For this reason, IAEA requires additional measures for assurance, such as containment and surveillance (C/S)

COMPENSATORY MEASURES …

- Containment and surveillance
  - Video cameras
  - Tags and seals
  - Portal monitors
- Process monitoring
  - Solution levels

… ARE INSUFFICIENT

- Can complementary measures fully compensate for inadequate material accountancy?
  - Not likely, because in the event of a loss of continuity of knowledge, there is no fallback to quickly confirm that no diversion has occurred
- Voluminous data (video capture, seal verification)
- False alarms can be overwhelming if very low thresholds are set (process monitoring)
- In the event of an alleged diversion or theft, the claim must be confirmed or disproved rapidly by accounting for all material

THEFT

- Weapons-usable materials must also be protected against violent theft by terrorist groups with state-of-the-art capabilities
- Even though the consequences of such a theft could threaten the world, the prevailing view is that physical protection is a national prerogative
  - attempt to develop binding international standards failed
  - IAEA only has advisory role
- The United States probably has the world's most stringent set of regulations and procedures for the physical protection of weapon-usable materials, both military and civil --- yet even here, security often falls short

SECURITY OVERSIGHT

- U.S. nuclear facilities that possess certain quantities of special nuclear materials are required to protect against the design basis threat (DBT) of theft
  - A group of attackers with well-defined characteristics, skills, arms and equipment
  - Different DBTs apply at NNSA and NRC-licensed facilities
- Radiologically hazardous facilities (such as power reactors) must protect against the DBT of radiological sabotage (believed to be less severe than the theft DBT)
- To protect against the DBT, nuclear facilities must deploy a security force of armed responders capable of immediately responding to an attack
- NRC and NNSA assesses security force performance through periodic “force-on-force” tests
  - Security plans that look acceptable on paper often have vulnerabilities that are revealed only during performance testing

INADEQUATE STANDARDS

- DBTs do not realistically reflect current threats, e.g. the 9/11 threat (four 4-5 member teams)
  - NRC DBTs are known to be set, by design, to levels well below 9/11 threat and current “postulated threat”
    - number of adversaries
    - weaponry (e.g. armor-piercing projectiles)
    - tactics (e.g. multiple truck bombs, ruses, diversions)
    - Insider characteristics (active, passive, nonviolent, violent)
  - NNSA increased the DBTs twice after 9/11 to a level believed to be far higher than NRC’s, but these imposed such a significant burden on facilities that they were subsequently rolled back

SECURITY FAILURES (NNSA)

- Facilities fail force-on-force tests far too often
- NNSA: April 2008 force-on-force test at the plutonium storage facility (Superblock) at Lawrence Livermore National Laboratory found "significant weaknesses" in the protective forces' performance against the adversary threat identified in DOE's 2003 DBT, particularly during force-on-force scenarios and in other types of performance assurance testing." (GAO-09-321, March 2009)

SECURITY FAILURES (NRC)

- NRC (radiological sabotage):
  - Before 9/11, about 50% of reactor sites failed force-on-force tests
  - Between Nov 2004-Dec 2008, 4 reactor sites failed force-on-force exercises out of 88 evaluated (5% failure rate)
  - 2 out of 23 in 2008 alone (10% failure rate)
  - In 2009: 3 sites failed out of 22 (14% failure rate)
- Performance seems to be declining – better than 50%, but not good enough
  - This figure does not reflect a larger number of sites that passed the test but still had significant weaknesses
  - The DBT for radiological sabotage is less severe than the DBT for theft of plutonium
  - Does not include data for two NRC-licensed Category I (HEU) fuel cycle facilities in the U.S. (security inspection results are classified)


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3 EYEWITNESS NEWS

CAN SECURITY BE RISK-INFORMED?

- “Risk-informing” generally means using quantitative safety information from probabilistic risk assessments (PRA) in regulatory processes
- Strictly speaking, security cannot be “risk-informed” because it is impossible to quantify the probabilities of deliberate actions (e.g. terrorist attacks)
  – Initiating event probabilities are unknown
  – Probabilities of various outcomes cannot be predicted because of the ability of failure modes to be self-corrected

“RISK-INFORMING” SECURITY: CODE FOR “WEAKENING” SECURITY?

- At NRC, “risk-informing” security is currently being discussed primarily in the context of relaxing security requirements for plutonium when it is in forms that some assert are less attractive for terrorists than separated plutonium; e.g. mixed-oxide (MOX) fuel assemblies
- However, these determinations make implicit assumptions about adversary capabilities that may not be conservative enough to provide adequate protection
  - For instance, they do not take into to account the potential for adversaries to quickly “disassemble” a MOX fuel element to facilitate theft, or the fact that the chemistry to separate plutonium from uranium is straightforward

DEREGULATING MOX SECURITY

- A single MOX fuel element could contain 20 to 35 kg of plutonium – enough for several bombs
- U.S. industry has complained that current security requirements for plutonium are unduly burdensome for mixtures such as MOX fuel
  - Until recently, MOX fuel was considered “Category I” material by NRC, requiring the same level of security as separated Pu
  - In 2007, NRC changed its regulations to exempt all MOX fuel with Pu < 20% from Category I when stored at reactors
- NRC is currently developing a proposal to reduce security on MOX fuel during transport because industry has complained about the cost of having to meet Category I requirements during shipment
- If enacted, this would set a terrible example for Russia, Japan and other countries with significant quantities of plutonium

NRC COMMISSIONER BILL MAGWOOD ON MOX SECURITY

Second, I disapprove the staff's proposal to change the categorization of MOX fuel for the purpose of fuel transportation. While a reasonable technical debate may be conducted regarding the attractiveness of MOX to a potential adversary, this subject has not yet matured to the stage where the Commission should consider a change in current policy. There are no commercial proposals to use MOX and the only source of MOX expected in the U.S. in the foreseeable future is the project governed by the Department of Energy. Therefore it is prudent to leave the transportation of the fuel as Category I.

Vote of NRC Commissioner Bill Magwood, 17 June 2010

SECURITY AND SAFEGUARDS "BY DESIGN"

- In a 2003 hearing on the U.S. MOX plant construction authorization, NRC and the NNSA contractor both argued that they were not required to provide design features for security and material accounting systems
- As a result, the facility is now being built according to a design that did not undergo a substantive security and safeguards review by NRC staff
  - Costly retrofits may have to be made later

MOX PLANT DESIGN PROBLEMS

- “Intervenors point to three documents as providing information that ‘not only is the design of the proposed MOX facility inadequate to support item verification and alarm resolution, but that [the Applicant] has no plans to correct its design problems.’” --- NRC Staff, August 23, 2010.

REQUIRING “SAFEGUARDS BY DESIGN”

- NRC should adopt a rule explicitly requiring that facility designs be optimized for effective application of material control and accounting, security and international safeguards measures
- Results of diversion path analyses and vulnerability assessments should be part of the application
- NRC approval of “safeguards by design” approach should be required before facility construction can commence
- Safeguards by design can be useful but is not a panacea

ISSUES FOR MATERIAL ACCOUNTANCY DESIGN REVIEW

- Past examples of design flaws that have caused problems for material accountancy include
  - Excessive scrap generation
  - Inadequate analytical laboratory capacity
  - Holdup accumulation
    - Careful choice of materials and geometries for gloveboxes and process equipment can help to reduce residual holdup
    - NDA measurement must be able to accurately account for significant amounts of holdup

ISSUES FOR PHYSICAL PROTECTION DESIGN REVIEW

- Goal of the physical protection design review is to reduce burden on armed responders and other operational features
  - Delay provided by layout
  - Eliminate areas of single-point vulnerability
  - Vault wall and door thicknesses
  - Vehicle bomb attack resistance
  - Aircraft attack resistance

IAEA SAFEGUARDS ON U.S. PLANTS

- Disparities in obligations between weapon- and non-weapon states continue to challenge the credibility of the international safeguards system
  - More sensitive facilities in weapon states means a smaller fraction will be under IAEA safeguards
- The U.S. should lead by example and place all proliferation-sensitive fuel cycle facilities on the IAEA eligible facilities list
  - This would entail providing design information to the IAEA upon the decision to construct

IAEA SAFEGUARDS

- Two facilities not currently on the eligible list are
  - U.S. MOX plant
  - GE-Hitachi laser enrichment facility
- A new financing mechanism for weapon-state verification is also necessary
  - IAEA is reluctant to use scarce resources at facilities in states that already have nuclear weapons
- Internationalization of all sensitive fuel cycle facilities could provide a non-discriminatory framework for application of safeguards in weapon and non-weapon states

CONCLUSIONS

- Safeguards and security requirements for weapon-usable nuclear materials must be set at the highest levels and based on conservative assessments of current and future threats
- Binding international standards for security should be enacted
- Requirements should not be watered down because the resources needed to adequately secure the closed fuel cycle are beyond what private industry is willing or able to provide

SUPPLEMENTAL INFORMATION

Case studies of material accountancy failures

PFPF

- PFPF (MOX fuel plant at Tokai-mura, Japan)
  - Began operation in 1988; by 1994, material unaccounted for (MUF) was nearly 70 kilograms
  - PNC (the plant operator) claimed the material was “residual holdup” that remained stuck to equipment after cleanout
  - IAEA could not verify this claim; wanted PNC to remove and clean out gloveboxes so holdup could be directly measured; dispute was not resolved until problem was leaked to the media in 1994
  - Cleanout and refurbishment took 2 years and $100 million; MUF was reduced to 9.5 kilograms

TOKAI REPROCESSING PLANT

- In January 2003, it was announced that the shipper-receiver difference at the Tokai Reprocessing Plant had reached 206 kilograms of plutonium after 25 years of operation
- JNC claimed this resulted from
  - plutonium stuck in fuel cladding hulls
  - plutonium discarded with high level waste
  - plutonium that decayed into americium
  - plutonium that never existed
- All these routes are associated with significant uncertainty; unlikely the discrepancy will ever be fully resolved

THORP LEAK

- At Thorp in 2004-2005, a leak in a pipe leading to an input accountancy tank went undetected for nine months
  - 83.4 cubic meters of spent fuel solution, containing 19 metric tons of uranium and 190 kilograms of plutonium ended up outside of the process line
- The plutonium shortfall was noticed but was initially not distinguishable from measurement error
- BNFL (2005): Nuclear Materials Accountancy System "is not designed to (nor is it intended that it should) be responsive to track material on a more real time basis."
- Yet BNFL and Euratom both claimed previously that "Near Real Time Materials Accountancy was fully operational" at Thorp
  - apparently a massive failure of material accountancy on the part of both the operator and the Euratom inspectors

CADARACHE MOX PLANT

- MOX plant operated from 1962-2004
- Approximately 8 kg Pu was estimated to have accumulated as residual holdup in gloveboxes
- However, after decommissioning began in March 2009, 22 kg Pu was recovered (nearly 2 SQ more than estimated), and the actual total may be 39 kg
- This means that both the plant operator and the Euratom safeguards inspectors were unable to detect a shortfall in the quantity of Pu on the order of 2-4 SQ for years or decades
  - ASN (French nuclear safety authority): "…the lack of detection of this underestimation during the operating period of the installation, as well as the late reporting of this event to the ASN, reveal a gap in safety culture."