Monitoring Nuclear Weapons and Nuclear-Explosive Materials
An Assessment of Methods and Capabilities

Committee on International Security & Arms Control
National Academy of Sciences

Steve Fetter, Study Co-Chair
CISAC…

• standing committee of the NAS
• established in 1980 to conduct off-the-record dialogues with a counterpart Soviet group
• a mixture of
  – senior academic analysts of international security & arms control,
  – individuals of long experience in the national nuclear weapons labs & the defense industry, and
  – retired leaders from the military, government, and arms-control diplomacy
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Motivation for the study

• Previous CISAC studies underlined key role of transparency, monitoring, and verification, both for
  – future of arms limitation among the nuclear-weapon states
  – keeping NEM from proliferation-prone states & terrorists
• In 2000, DOE requested that CISAC study potential for more comprehensive approach to nuclear-arms control
• Focus evolved to emphasize monitoring because
  – world events & new administration increased salience of nonproliferation & counter-terrorism relative to “arms control”
Scope of the study

- “Extent to which current and foreseeable approaches to transparency and monitoring can support verification for all categories of nuclear weapons—strategic and non-strategic, deployed and nondeployed—as well as for the nuclear explosive components and materials that are their essential ingredients.”

- “Increasing the categories of items subject to transparency and monitoring would be valuable—and may ultimately be essential—as we address the urgent and interrelated goals of reducing the dangers from existing nuclear arsenals, minimizing the spread of nuclear weaponry to additional states, and preventing the acquisition of nuclear weapons by terrorists.”
Scope of the study

• “The study has addressed the technical and institutional approaches and capabilities in transparency and monitoring that could be applied to any or all of these purposes.”

• “It has not tried to analyze or make recommendations about the choices in U.S. nuclear-weapon and nonproliferation policies and priorities that will continue to shape the context within which such approaches and capabilities might be applied.”
Magnitude of the monitoring challenge

- 30,000 nuclear weapons remain in the world
  - 95% U.S. and Russian
  - 5% in UK, France, China, Israel, India, Pakistan, possibly North Korea
- Moscow Treaty commits US & Russia to reduce operationally deployed strategic offensive nuclear weapons to 1700-2200 each by end of 2012
  - doesn’t include nonstrategic or non-deployed weapons
  - no transparency or monitoring provisions
    (declarations & monitoring under START expire 12-09)
  - doesn’t apply to other countries
The monitoring challenge

Enormous stocks of NEM exist:

<table>
<thead>
<tr>
<th></th>
<th>Military</th>
<th>Civil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEU</td>
<td>1840</td>
<td>60</td>
<td>1900</td>
</tr>
<tr>
<td>Pu (unirradiated)</td>
<td>260</td>
<td>230</td>
<td>490</td>
</tr>
</tbody>
</table>

These are metric tons (thousands of kilograms) IAEA definition of a “significant quantity” (SQ) – enough for a weapon – is 25 kg HEU, 8 kg Pu

Global NEM stocks > 100,000 SQ
The monitoring challenge

• These NEM stocks pose risks
  – more weapons in nuclear-weapon states
  – acquisition of nuclear weapons by states that don’t yet have them but do have NEM
  – illicit transfer to or theft by other states or subnational groups intending to make nuclear weapons.

• HEU and Pu are difficult to produce. Access to them is the limiting technical ingredient for acquisition of nuclear weapons.
The monitoring challenge

• Characteristics of NEM and nuclear weapons place limits on the capabilities of any system of transparency and monitoring

• Tensions between sharing information and maintaining security of stockpiles against attack, sabotage, and theft

• Tension about formal agreements v. informal arrangements
Weapons and Components

• Elements of a transparency & monitoring regime:
  – comprehensive declarations
  – measures to confirm declarations of weapon inventories
  – measures to confirm declarations of weapon dismantling, manufacture
  – measures to confirm destruction, manufacture of weapon components (pits, CSAs)
**Weapons: Declarations**

- Declarations can be made at various levels of detail:
  - aggregate inventories (total number of weapons)
  - by weapon type, status
  - by facility
  - itemized
- Comparable historical data would help build confidence
- “Secure declarations” can allow exchange of detailed data while retaining control over its release
  - encryption (separate key for each record)
  - message digests (secure hash for each record)
Weapons: Inspections

• Declarations can be confirmed with inspections of deployed and storage warheads
• Sampling greatly decreases number of inspections needed to gain confidence declaration is accurate
• START defined procedures for missile warheads; all other warheads in storage
• Two approaches for identifying weapons
  – templates: confirm that characteristics of object match those of a known weapon
  – attributes: confirm that characteristics of object are consistent with a nuclear weapon
Weapons: Template Identification

- Measure radiation signature
Weapons: Templates Identification

<table>
<thead>
<tr>
<th>Object</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warhead Type A, #1</td>
<td>0.8*</td>
<td>92</td>
<td>32</td>
<td>7.7</td>
<td>42</td>
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<tr>
<td>Warhead Type A, #2</td>
<td>0.9</td>
<td>90</td>
<td>31</td>
<td>8.2</td>
<td>45</td>
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<tr>
<td>Warhead Type A, #3</td>
<td>0.8</td>
<td>91</td>
<td>32</td>
<td>8.5</td>
<td>45</td>
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<tr>
<td>Warhead Type B</td>
<td>496</td>
<td>0.8</td>
<td>140</td>
<td>336</td>
<td>491</td>
</tr>
<tr>
<td>Warhead Type C</td>
<td>63</td>
<td>43</td>
<td>0.9</td>
<td>34</td>
<td>128</td>
</tr>
<tr>
<td>Warhead Type D</td>
<td>11</td>
<td>102</td>
<td>26</td>
<td>0.6</td>
<td>46</td>
</tr>
<tr>
<td>Warhead Type E</td>
<td>55</td>
<td>174</td>
<td>86</td>
<td>31</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Compare with known templates

Protect data; indicate “match” or “no match”
Weapons: Monitored Storage

- Real-time monitoring of storage weapons, weapon components
Weapons: Tags and Seals

• Tags uniquely identify objects
• Seals indicate tampering
Nuclear Explosive Materials (NEM)

• Basic structure of transparency and monitoring for NEM can be parallel to that for weapons and components:
  – comprehensive declarations of quantities & locations, plus info on chemical forms & isotopic composition
  – declarations of inventories of NEM surplus to military and civilian needs
  – provision for inspection of all declared facilities as well as of any undeclared suspicious activities
Nuclear Explosive Materials

- Transparency and monitoring can be made easier by reducing stocks and flows of NEM
  - down-blending excess HEU for use as reactor fuel
  - replacement of HEU fuels in research reactors
  - disposition of excess Pu
  - negotiated cutoff of production of NEM for weapons
  - nuclear fuel cycles for civil reactors that minimize or eliminate vulnerability of NEM
  - centralization under international control of all facilities capable of enriching uranium or separating Pu
Nuclear Explosive Materials

- Related measures to increase transparency and monitoring for NEM are:
  - improvements in national systems of MPC&A
  - strengthening of the IAEA safeguards regime, including universal applicability of the Additional Protocol and increased IAEA manpower and funding

- While technologies exist to achieve greatly improved monitoring for NEM, a strengthened international consensus on the value of doing this will be needed to solve cooperatively the problems involved.
Clandestine Stocks and Production

• Undeclared weapons can be obtained by:
  – clandestine retention of existing weapons
  – manufacture of new weapons
    • clandestine retention of existing NEM
    • clandestine production of NEM
  – transfer of weapons or NEM from another state
Clandestine Stocks

• Tools for detecting clandestine stocks:
  – National Technical Means (NTM)
  – Human sources
  – Audits of records
  – Physical evidence ("nuclear archaeology")
    • overall uncertainty ~2% for Pu
    • state might confidently hide enough NEM for tens (China) to hundreds (Russia) of weapons
Clandestine Production

• Tools for detecting clandestine production:
  – National Technical Means (NTM)
  – Human sources
  – Environmental sampling

• In general, production of NEM difficult to hide

• US intelligence has detected every program, and identified production facilities, before significant quantities of NEM were produced
  – Soviet Union, China, Israel, India, Pakistan, South Africa, Iraq, North Korea, Iran