Safe Transport of Radioactive Materials.

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RC-19
12th International Congress
International Radiation Protection Association
October 2008
RC-19 Course Overview

1. Radioactive material transport safety
   - History
   - Key safety provisions

2. Security in transport of radioactive material
   - Background
   - Security levels and measures

3. Interfaces between transport safety and security
Transport Safety and Security

- **Safety**
  - A concern since the 1950’s
  - Regulations are technically based (deterministic) and continuously reviewed and revised

- **Security**
  - The new kid on the block
  - Post 9/11 concern
  - More difficult undertaking than the safety regulations since the external environment is much more complex (threat based)

- Interfaces are sometimes complementary and sometimes conflicting
Regulating Transport Safety

- Radioactive materials: an industry “born regulated”
  - In the late 1940’s the unique properties capable of harming health and damaging property (fogging photographic film) were recognized

- 1953: UN Committee of Experts on the Transport of Dangerous Goods was formed
  - Charged to reduce the risks of the rapidly increasing international trade in dangerous goods
  - Created the well recognized classification and labeling system in use today

- 1956: International Atomic Energy Agency formed
  - Charged with “establishing standards of safety for protection of health”
Regulating Transport Safety (con’t)

- 1959: United Nations Economic and Social Council (ECOSOC) requested that IAEA be entrusted with drafting recommendations on safe transport of radioactive material
  - Consistent with the Committee of Experts principles for other dangerous goods
  - Formulated in consultation with the UN and relevant specialized agencies (e.g., International Civil Aviation Organization and International Maritime Organization)

- The ECOSOC request complimented the IAEA’s mandate to develop safety standards
IAEA Transport Regulations

- Published in 1961 as the “Regulations for the Safe Transport of Radioactive Material”, Safety Series No. 6

  Berlin wall is constructed (some ideas do not stand the test of time!)

- Revised in 1964

  Specific tests added to simulate severe accident damage

  Beatlemania sweeps the USA
Transport Regulations History

- Revised in 1967
  - Type B(U) and B(M) package distinction made

- Revised in 1973
  - Skylab manned space missions completed (and burns up on re-entry in 1979!)
  - First human heart transplant (South Africa)
More History – Where Were You When?

- Revised in 1985
  
  200 m immersion test added
  Dynamic crush test added

- Revised in 1996
  
  Hole in ozone layer discovered
  
  Type C packages introduced
  
  Garry Kasparov beats IBM’s Deep Blue (and loses in 1997)
Transport Safety Implementation

- IAEA Transport Regulations issued in 2000 as TS-R-1
- Uniform adoption requires national, regional and international commitment
- The IAEA Transport Regulations are extensively used as the basis for national and international regulations
  - 30 of 31 nuclear power countries and 88% of responding countries use them as the basis for legally binding regulations
International Application of the IAEA Transport Regulations

- The Transport Regulations serve as the basis for radioactive provisions in the UN Transport of Dangerous Goods – Model Regulations

- The Model Regulations are also applied in
  - Convention on International Civil Aviation
  - International Convention for the Safety of Life at Sea

- Other regional agreements (e.g., MERCOSUR/MERCOSUL, ADR/RID) also use the Transport Regulations as their basis
Results of Widespread Adoption

- No deaths or serious injuries from the radioactive nature of the materials
- Compliance with regulations reported to be “good” by Member States and carriers
- Factors important to consistent compliance
  - Uniform regulations among countries and modal organizations
  - Consistency with other dangerous goods regulations
  - Uniform interpretation and application
  - Avoiding unique regulatory requirements
Purpose-built Regulations From the Start

- Protect persons, property and environment from hazards posed by radioactive material during transport

- Radioactive materials present an enormous range of potential hazards during transport
  - Solid, liquid and gaseous form
  - Short- to long-lived radionuclides
  - All radiation types (α, β, γ and neutron)
  - Insignificant to high decay heat
  - Small to very large activity per package

- All hazards must be protected against during transport
How the Transport Regulations Work

- Four simple objectives
  - Containment to prevent spread of material
  - Shielding to prevent harmful radiation levels
  - Criticality safety for fissile material
  - Heat management to safely dissipate decay heat

- Primary responsibility placed on consignor ("shipper") since that entity best knows the material being packaged and shipped

- Carrier actions limited to a few simple operational controls
  - Limiting accumulation of packages
  - Separation from persons and other cargo
Major Steps in Preparing a Radioactive Material Shipment – a Review

1. Identification
2. Classification
3. Hazard communication
4. Packaging
5. Other controls

ANYONE PREPARING A RADIOACTIVE MATERIAL SHIPMENT NEEDS IN-DEPTH TRAINING!
Prefering a Radioactive Material Shipment

Identification

Classification

Hazard
- Communication
  - Shipping papers
  - Marking
  - Labeling
  - Placarding

Packaging
- Exceptioned
- Industrial
- Type A
- Type B
- Type C

Other Controls
- Dose rate limits
- Contamination limits
- Exclusive use
- Criticality controls
- Training
- Stowage and segregation controls
Identification

- Fully identify and characterize the contents to be shipped
  - Form ("special form" or not?)
  - Identify and activity of each radionuclide; total activity
  - Identity and mass of fissile radionuclides
  - Subsidiary chemical hazards
  - Activity concentration or surface contamination (fixed and non-fixed) if appropriate
  - Special considerations (incorporation into a manufactured item, etc.)
Classification

- Carefully and fully classify the material to be shipped
  - Is it radioactive by definition?
  - Can it be shipped as an excepted quantity?
  - Can it be shipped as a “low specific activity material”?
  - Can it be shipped as a “surface contaminated object”?
  - Type A, Type B or Type C quantity?
  - Fissile excepted?
  - Uranium hexafluoride?
Hazard Communication

- Carriers, emergency responders, consignees and other personnel need to be aware of the hazards presented by the package
  - Shipping documentation (available for inspection and consideration during emergencies)
  - Marking on package (identifies the type of package, consignor/consignee, etc.)
  - Labeling on package warns of the presence of radioactive material and indicates the radiation level (Yellow-III, Yellow-II, White-I)
  - Placarding on conveyance warns of the presence of radioactive material at a distance
Packaging

- Proper packaging is key to hazard control
- Unpackaged (very low hazard materials)
- Non-accident resistant
  - Excepted
  - Industrial
  - Type A
- Accident resistant
  - Type B
  - Type C
- Fissile
- Uranium hexafluoride
Other Controls

- Other controls assist in limiting hazards to personnel and property
  - Dose rate limits
  - Contamination limits
  - Exclusive use requirements (high dose rates)
  - Criticality controls (limits on package accumulation)
  - Training
  - Stowage and segregation controls
Transport Safety Results

- The combined effect of the transport requirements on consignors and carriers results in a very high level of safety by all modes of transport.

- Radioactive material shipments can move internationally without serious impediment due to consistent national and international regulations.

- Diligence by consignors and carriers is key to maintaining this ability.
“Four Faces of Nuclear Terrorism¹”

1. Acquire and use a nuclear weapon

2. Acquire sufficient material, fabricate and use a crude nuclear weapon

3. Strike nuclear power plants and other nuclear facilities

4. Acquire material, fabricate and use a radiological dispersion device (a.k.a, “dirty bomb”)

¹ C.D. Ferguson, et al, Center for Nonproliferation Studies, USA
Transport Security for Radioactive Material

- Fissile ("nuclear") material has been secured under the Convention on the Physical Protection of Nuclear Material since 1979 – including during international transport

- Similar internationally binding security provisions do not apply to non-fissile radioactive material
The Transport Security Aspects of the “Four Faces”

- 1 and 2 – physical protection of weapons usable materials
  - International Convention on the Physical Protection of Nuclear Material
  - INFCIRC/225, Rev. 4 (corrected)

- 3 – not applicable to transport (sabotage of facilities)

- 4 – transport security needs to be addressed thoroughly to prevent adversaries acquiring radioactive material during transport
Addressing Transport Security

- UN Committee of Experts addressed security of all dangerous goods in 12th Edition of the Model Regulations
  - Consulted IAEA for definition of “high consequence” radioactive material and exceptions (nuclear material covered by INFCIRC/225)

- IAEA began a review of transport security to determine if additional measures were needed

- International basis
  - No convention like nuclear material
  - Security is traditionally a State responsibility (aversion to additional obligations)
  - Code of Conduct on the Safety and Security of Radioactive Sources includes some requirements but is voluntary
Establishing Transport Security Requirements for Non-nuclear Material

- IAEA initiated efforts in 2003 to
  - Determine appropriate transport security levels and thresholds
  - Recommend appropriate security measures for each security level

Radioactive Source Security is Being Addressed Already

- “Code of Conduct on the Safety and Security of Radioactive Sources” and “Guidance on the Import and Export of Radioactive Sources”
- Builds on an activity-based categorization
  - D-values calculated on basis of ability to cause “severe deterministic effects”
  - Category 1 ≥ 1,000 D
  - Category 2 ≥ 10 D
Considerations in Setting a Transport Security Threshold

1. Current UN Model Regulation threshold
   - 3,000 $A_1$ or 3,000 $A_2$
   - Uses well established Q-system and A-values

2. Code of Conduct applicable to radioactive sources

What basis should be used for specifying security thresholds for non-fissile radioactive material in transport?
Possible Malicious Use Exposure Pathways

- Radiation exposure - surreptitious placement of a source
  - Pubic area
  - Private area (targeted)

- Dispersion of material
  - Internal exposures (inhalation and plume dose, resuspension, etc.)
  - External exposures
  - Evacuation/resettlement
    - Social disruption
    - Economic disruption (denial of use, cost of cleanup, etc.)

- RDDs are most effective as “weapons of denial”
A simple planar model was used to examine potential malicious dispersion consequences

Chosen parameters

- 1 km²
- 1,000 mSv lifetime dose (ICRP 82)
- IAEA TECDOC-955 dose conversion factors for long term dose from deposition
Transportation Security Consequence Evaluation

\[ A = \frac{D \times Area}{CF_4 \times RF} \left[ \frac{1}{(OF \times SF) + (1 - OF)} \right] \times \frac{1TBq}{10^9 kBq} \]

\( A = \) activity (TBq)
\( D = \) ICRP lifetime dose value (1000 mSv)
\( CF_4 = \) long term dose conversion factor for deposition
\( \text{Area} = \) surface area covered (10^6 m^2)
\( OF = \) occupancy factor (0.6)
\( SF = \) shielding factor (0.16)
\( RF = \) release factor (0.1)
Transport Security Thresholds

- Many considerations were taken into account
  - Need for consistency with the Code of Conduct for radioactive sources
  - Draft security guidance in TECDOC-1355 for radioactive sources
  - Need for consistency with already familiar radioactive transport safety concepts and terminology
  - Results of the widespread dispersion calculation

- IAEA meetings concluded
  - $3,000 A_2$ except for radionuclides included in the Code of Conduct
  - $10 D$ (Category 2) for radionuclides included in the Code of Conduct
# Example Radioactivity Thresholds

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Security Threshold (TBq)</th>
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</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>0.6</td>
</tr>
<tr>
<td>Cf-252</td>
<td>0.2</td>
</tr>
<tr>
<td>Cs-137</td>
<td>1</td>
</tr>
<tr>
<td>Hg-203</td>
<td>3,000*</td>
</tr>
<tr>
<td>I-131</td>
<td>2,100*</td>
</tr>
<tr>
<td>Mo-99</td>
<td>1,800*</td>
</tr>
<tr>
<td>Pu-238</td>
<td>0.6</td>
</tr>
<tr>
<td>$U_{nat}$</td>
<td>Unlimited*</td>
</tr>
</tbody>
</table>

* Limited by 3,000 $A_2$
Security Levels

- The threshold can be used to define materials requiring "basic" and "enhanced" security measures.
- Some materials do not need specific security measures.
Considerations in Setting Transport Security Measures

- **Consistency with the UN Model Regulations**
  - Two security levels (basic and enhanced) determined to be sufficient
  - Minimizes additional costs and complexity
  - Minimizes likelihood of denial of shipments

- **Thresholds based on consequence evaluation and consistency with the Code of Conduct**
  - Strong beta/gamma emitters used in significant quantities are included in the Code of Conduct
  - Other radionuclides captured at the 3,000 A₂ level
Basic Transport Security Measures

- General security provisions
  - Competent Authority, at its discretion, should provide threat information to operators
  - Operators should consider security requirements commensurate with their responsibilities
  - Transfers limited to appropriately identified carriers/consignees
  - Use of appropriate security measures at in-transit storage sites
  - Procedures to initiate inquiry for overdue shipments and, if lost or stolen, to initiate efforts to locate and recover
Basic Transport Security Measures (continued)

- Security locks
  - Secure and closed conveyances or sealed packages >500 kg secured to the vehicle
- Security awareness training
- Personnel identity verification
- Security verification (inspection) of conveyances
- Written instructions with required security measures
- Security related information exchange by operators
- Trustworthiness verification
Enhanced Security Measures

- Apply to packages exceeding threshold
- Competent Authority should identify carriers and consignors
- All operators should develop, implement and periodically review a security plan
  - Allocation of responsibilities
  - Records of packages/materials transported
  - Review of operations and assessment of vulnerability
  - Identification of measures used to reduce security risks
  - Procedures for reporting and dealing with security threats, breaches, and incidents
  - Evaluating, testing and review/update of security plan
  - Measures to ensure information security
  - Measures to limit distribution of sensitive information
  - Measures to monitor the shipment
Enhanced Security Measures (continued)

- State should assign **responsibility for security plans** (may be incorporated into other plans)
- Operators should ensure appropriate **response plans**
- **Advance notification**
  - Consignor should notify consignee of planned shipment, mode, and expected delivery time
  - Consignee should confirm receipt/non-receipt
  - Consignor should notify receiving/transit States (if required)
Enhanced Security Measures (continued)

- **Tracking devices**
  - When appropriate, transport telemetry or other tracking methods or devices should be used
    - Ranging from bar code to more sophisticated near real-time tracking systems

- **Carrier should provide ability to communicate from conveyance**

- **Additional provisions for road, rail, and inland waterway**
  - Carriers should ensure operational readiness of devices, equipment, etc.
  - Continuous attendance or secure parking of road conveyance
States should consider enhancing measures based on a DBT, prevailing threat or nature of the material, inter alia:

- Additional training
- Carrier licensing, approval of their security plans, and auditing
- Use of automated real-time tracking
- Use of guards
- Evaluation of potential for sabotage
- Transfer of security responsibilities during shipment
- Review of security plans, holding exercises, etc.
<table>
<thead>
<tr>
<th>Component</th>
<th>Safety</th>
<th>Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Hazard communication</td>
<td>√</td>
<td>✗</td>
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<tr>
<td>Packaging</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Other controls</td>
<td>√</td>
<td>√</td>
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Safety and Security Interfaces

- Most interfaces are complementary (i.e., are neutral or helpful to the other discipline)
  - Classification (hazard & potential consequences)
  - Packaging (robust packages & delay)
  - Exclusive use vehicle (radiation protection & access control)

- Some interfaces must be carefully managed
  - Information security (written, verbal, cyber)
  - External communication (labeling, marking, placarding)

- Where warranted, pragmatic approaches may be needed (e.g., escorts providing hazard communication “as needed”)

Efforts Are Underway to Implement Transport Safety and Security Requirements

- Many countries already use TS-R-1 as the basis for safety requirements
- Many countries base their dangerous goods regulations on the Model Regulations/ICAO/IMO/etc. so security requirements are being emplaced
- Efforts are underway to assist other countries to do likewise
  - IAEA missions (both safety and security)
  - United States (NNSA Global Threat Reduction Initiative) security support
  - EU, Australia and other regional support
- Assistance available to countries includes
  - Detailed training course (NNSA/IAEA)
  - Security assessment and upgrades (national- and operator-level): both NNSA and IAEA
The Challenge is in the Future

- Countries need to address transport security for radioactive material
- IAEA implementing guide provides a good basis
- An understanding of the transport threat environment must be developed to inform the regulatory process
- Regulatory staff, shippers and carriers must be trained to implement security requirements (licensing, inspection, etc.)
- **Transport must be made secure to prevent “weak link” access to high-risk radioactive material!**