Relevancy of NMMSS to the Nonproliferation Challenges of Preventing the Spread of Nuclear Materials and Technologies

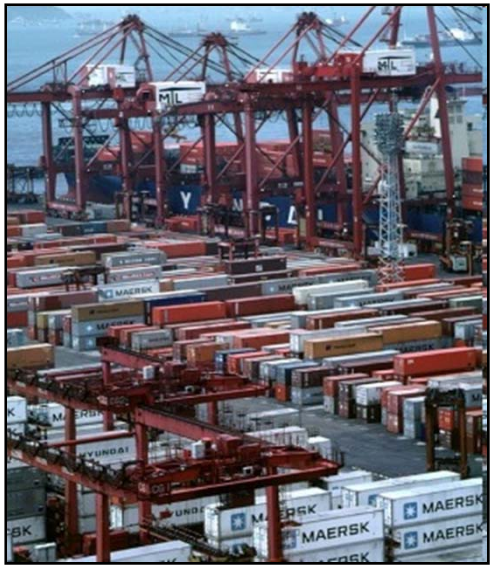
Steve Baker, Oak Ridge National Laboratory

Proliferation Threat – Why be Concerned?

- The overriding threat to U.S. and global security is the proliferation or terrorist acquisition of nuclear, chemical, or biological weapons (collectively called weapons of mass destruction, or WMD) and delivery systems.
- Numerous countries are capable of or openly striving to acquire nuclear weapons and other WMD.
- The emergence of terrorist groups with explicitly stated intentions to acquire and use nuclear, radiological, chemical, or biological weapons against the U.S. and others who do not espouse their political, cultural, or religious views is equally threatening.
- A WMD event will change human history.

Current Trends are Intensifying Proliferation Threats

- **Globalization**
  - Increasing transshipment trade
- **Modernization**
  - Technology advances and ease of intangible transfer of technology
- **WMD Brokering**
  - Front companies, “offshore” procurement networks and black-market supply networks
- **Terrorism**
  - Threat of development and use of WMD by sub-national groups
- **Secondary Proliferation**
  - Proliferants are themselves now suppliers of WMD commodities and know-how.



Nonproliferation – Objective

- Prevent the proliferation of materials, equipment, and technologies associated with:

  Weapons of Mass Destruction (WMD)
  - **Nuclear**
  - Chemical
  - Biological
  - Delivery Systems

From the Dawn of the Nuclear Age, Nonproliferation Has Been Recognized as Difficult

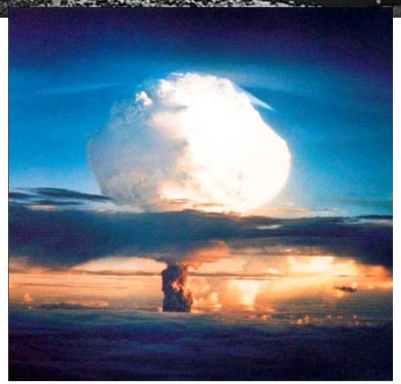
"I want to express my utmost sympathy with the people who have to grapple with this problem [the spread of nuclear weapons capabilities], and in the strongest terms urge you not to underestimate its difficulty."

J. Robert Oppenheimer, "Father" of the atomic bomb and first director of Los Alamos National Laboratory

Nuclear Weapons in Perspective: The Ultimate WMD

- The explosion at the Murrah building in Oklahoma City (4/19/95)
  - **Equivalent Energy: 1.5 tons of TNT**

- The Hiroshima atomic bomb (8/6/45) was 10,000 times that of Oklahoma City; a 40-mile-long line of rental trucks!
  - **Equivalent Energy: 15,000 tons of TNT**



- Mike, one of the world's first thermonuclear explosions (11/1/52), was 6,900,000 times that of Oklahoma City!
  - **Equivalent Energy: 10,400,000 tons of TNT**

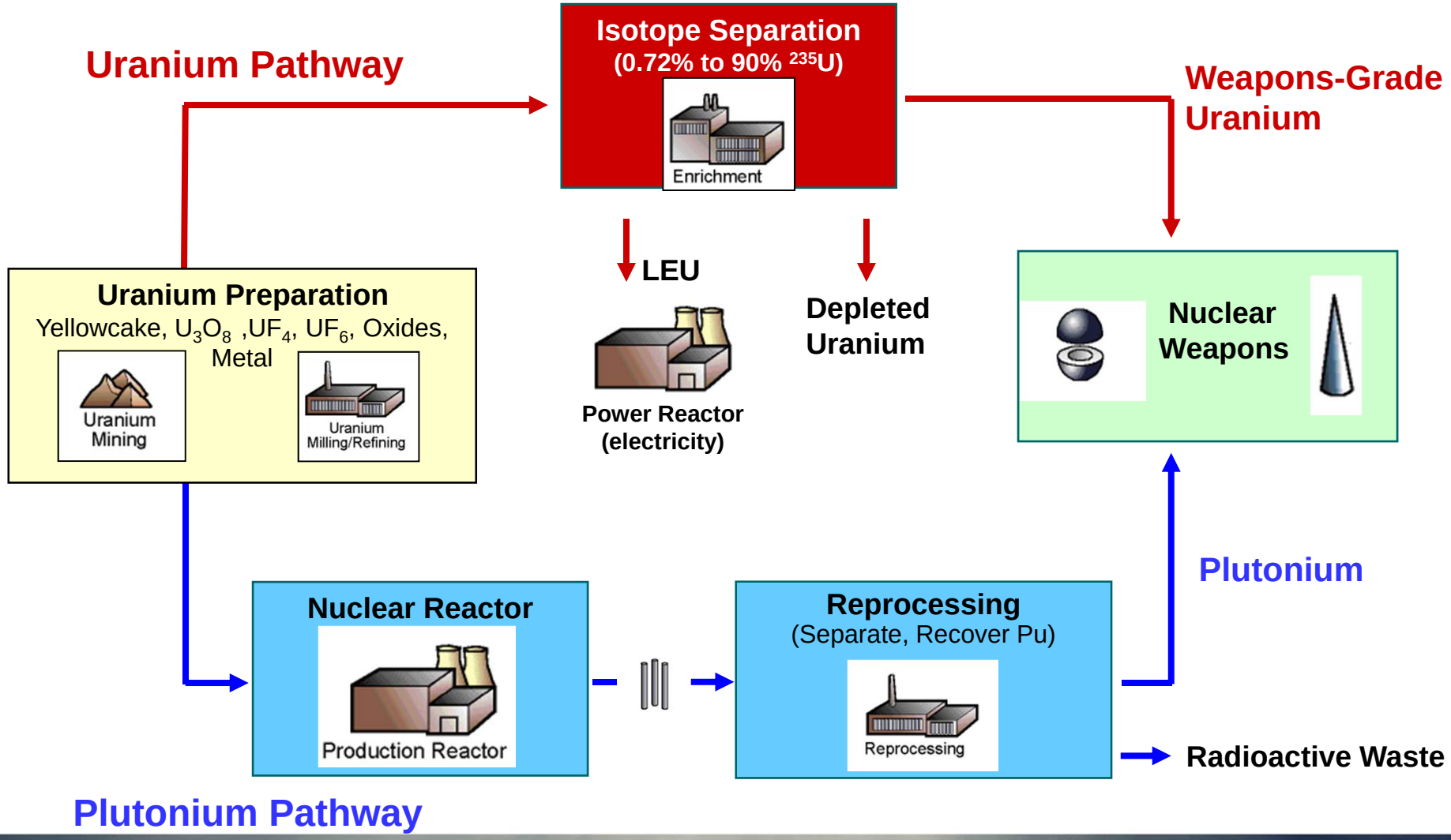
Compare Nukes to Radiological Dispersal Devices (RDDs) or Weapons of Mass "Disruption"

- Also known as "Dirty Bombs"
- Explosive disperses radioactive material, e.g.
  - Cobalt-60
  - Cesium-137
  - Iridium-192
- Not capable of producing a nuclear yield
  - no "fission"
- Incites fear, panic, and make facilities and land unusable
  - Large scale casualties very unlikely
  - High psychological and social impacts
  - Enormous cleanup costs

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

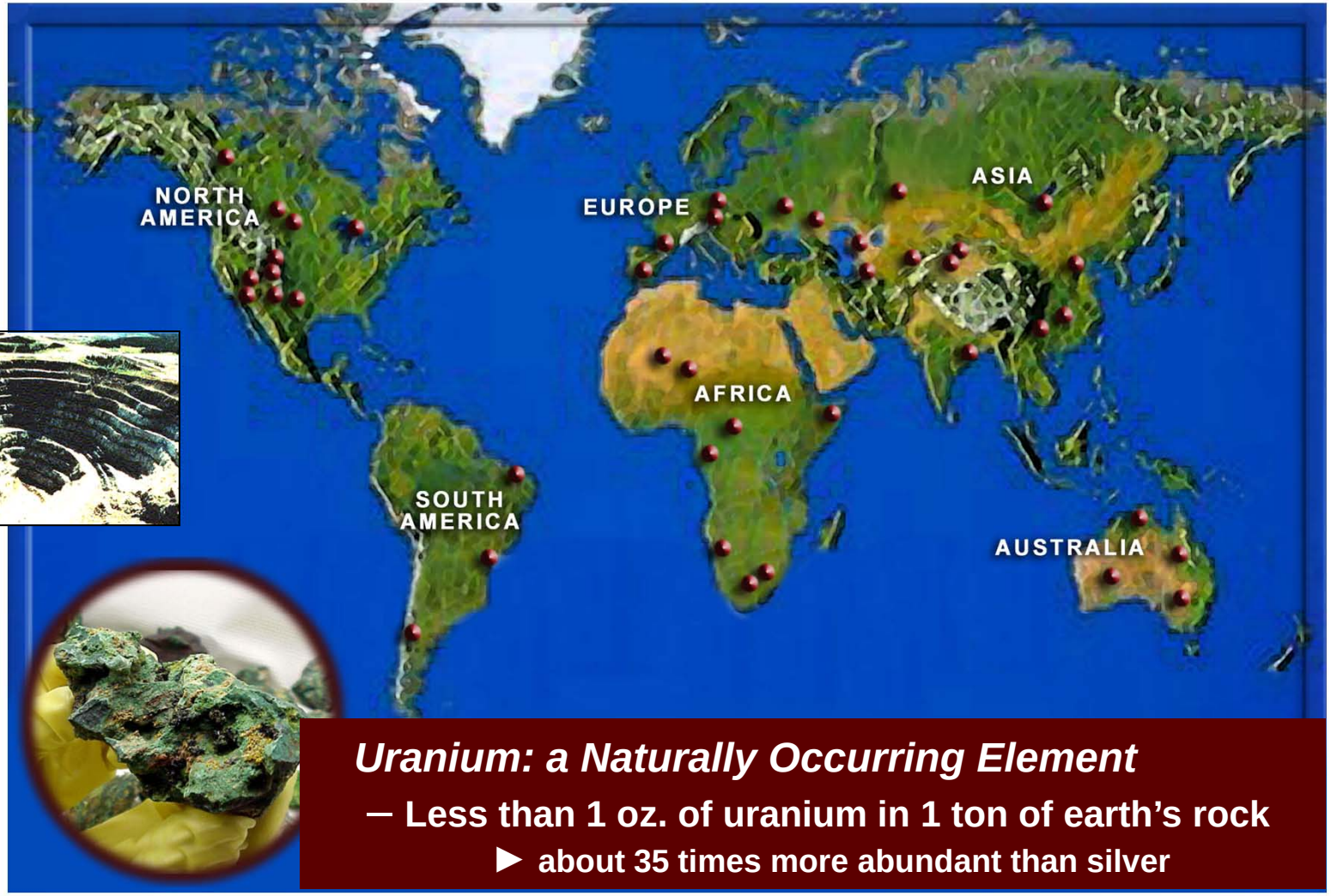
Two Production Pathways For Nuclear Weapons

Uranium Enrichment or Plutonium Production



NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Both Production Pathways Require Significant Quantities of Natural Uranium



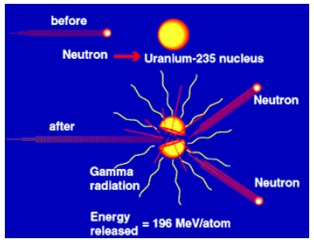
Uranium: a Naturally Occurring Element

– Less than 1 oz. of uranium in 1 ton of earth's rock

► about 35 times more abundant than silver

Natural Uranium Cannot be Used Directly in Nuclear Weapons

- **Natural uranium obtained from mining consists primarily of two components (i.e., isotopes)**
  - Fissile component (<1% of uranium) → U^{235}
  - Non-fissile component (>99% of uranium) → U^{238}



- **Most uses of uranium require higher concentrations of the fissile component**
  - Commercial reactors: ~4%
    "Low Enriched Uranium"

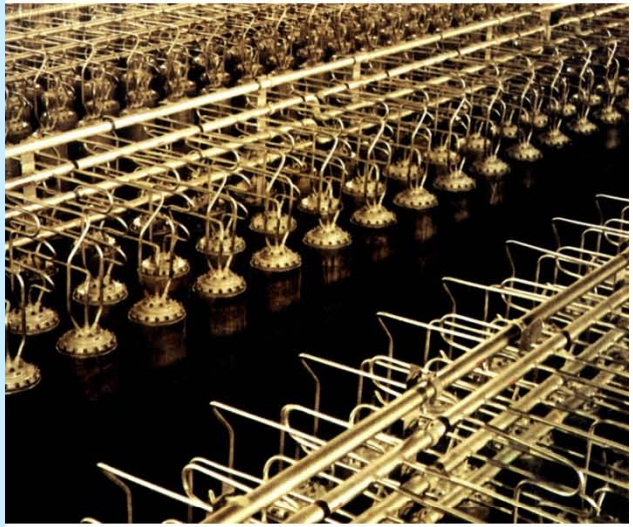
  - Nuclear weapons: ~90%
    "Weapons Grade Uranium"

- **1st Production Pathway → Uranium enrichment – a separation process in which the fissile (i.e., U^{235}) component of uranium is increased**
  - Technically difficult
  - Large-scale operation

How Can Uranium Be "Enriched"?

Today's Technology of Choice: Gas Centrifuge Process

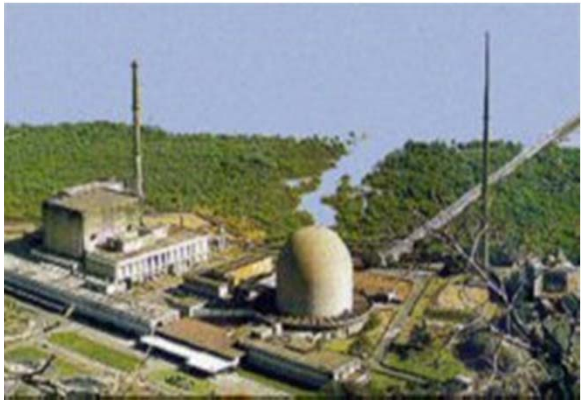
- Rotor spins at very high speeds
- Uranium in the form of a gas compound is concentrated next to the rotor wall
- The heavier component (U^{238}) tends to be closer to the wall than the lighter component (U^{235})
- The amount of separation of the two components increases with rotor speed and rotor length
- An individual centrifuge can only achieve slight separation
- Typically need several thousand machines connected in a cascade

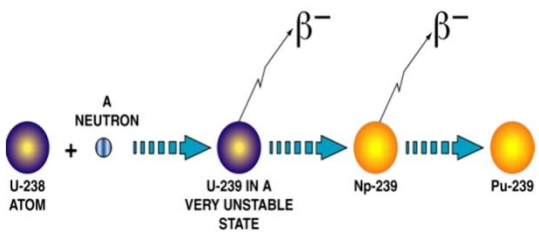


Centrifuge Cascade

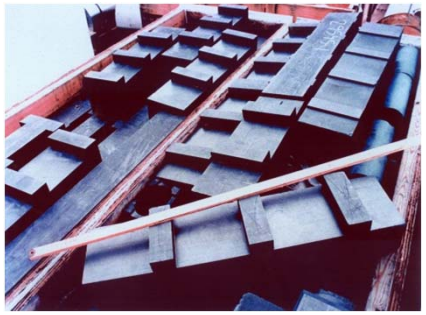
2nd Production Pathway – Plutonium Production

Man-Made Material Produced in a Reactor





- All reactors can produce plutonium
  - Natural uranium reactor requires import/production of heavy water or graphite
  - Other reactor types require import/production (i.e., enrichment) of low-enriched U-235
- All plutonium contains several isotopes
  - High purity Pu-239 is preferred for weapon use
- Plutonium production requires both reactors and "reprocessing" (i.e., separation of Pu-239 from other materials in the irradiated fuel rods)



NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Why Are Special Nuclear Materials and the Technologies to Produce Them Especially Important?

"The only difficult thing about making a fission bomb of some sort is the preparation of a supply of fissile material of adequate purity; the design of the bomb itself is relatively easy."

A "button" of HEU

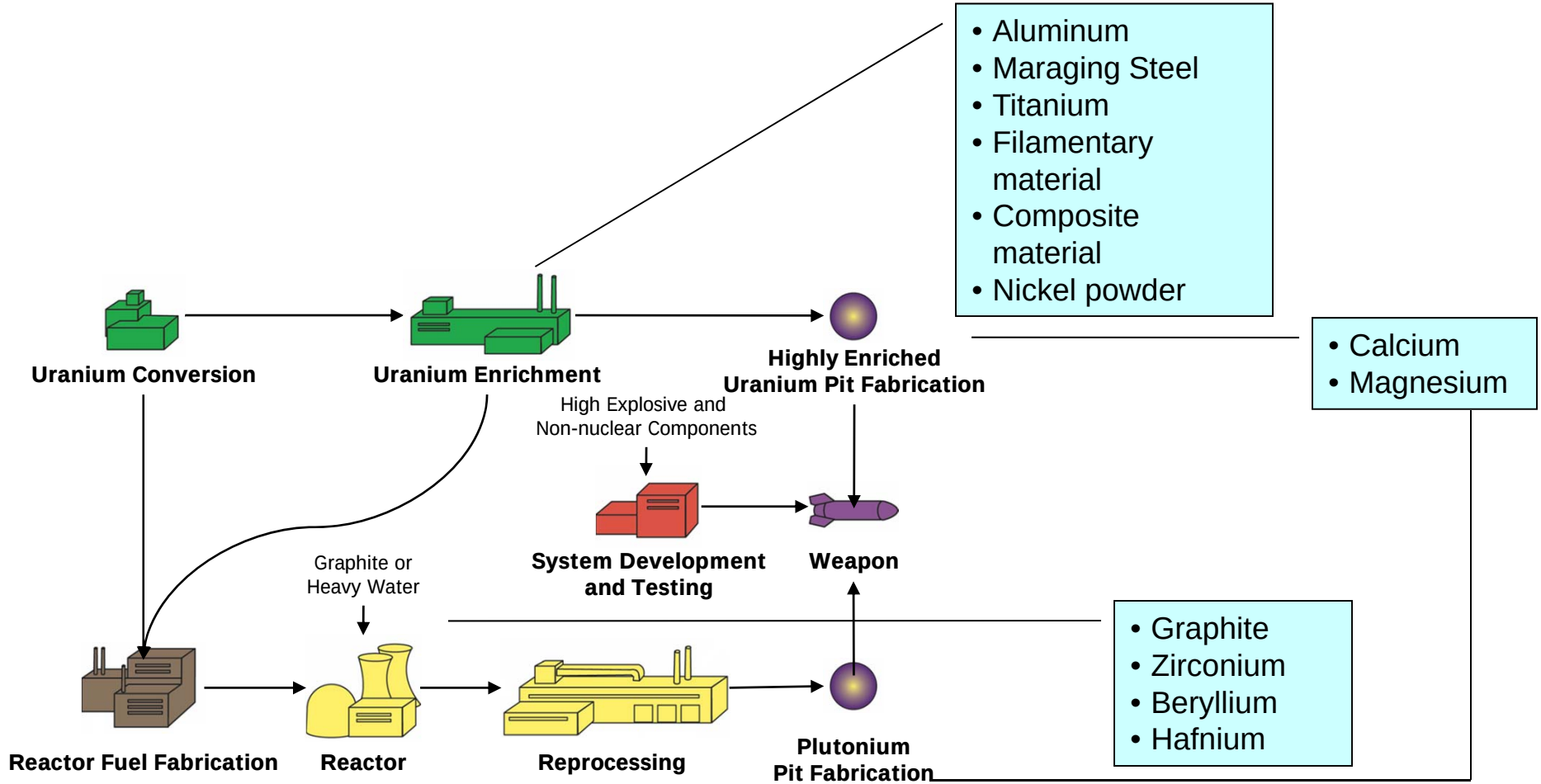
Plutonium ring

John Foster

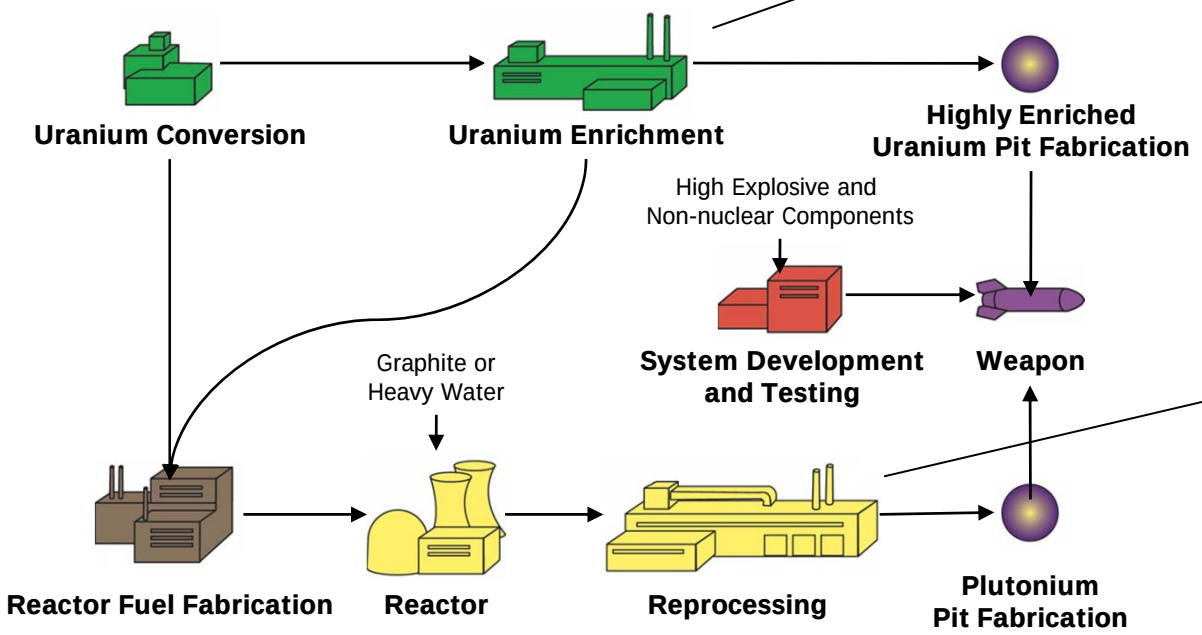
Former Director of the DOE Lawrence Livermore National Laboratory (LLNL)

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Extensive **Material** Requirements for Production of Special Nuclear Materials



Extensive **Industrial Equipment** Requirements for Production of Special Nuclear Materials

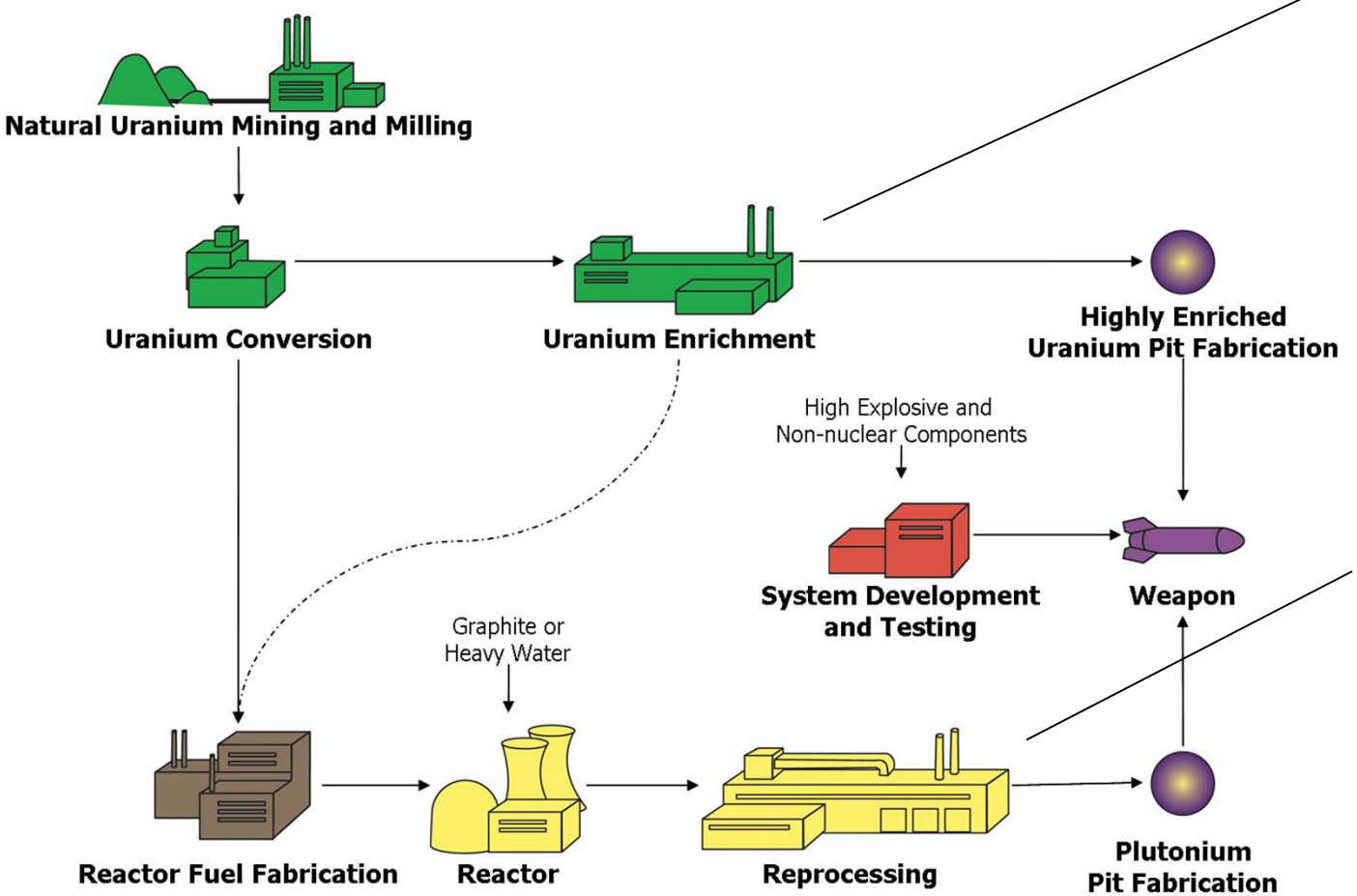


- Machine tools
- Flow/Spin forming machines
- Filament winding machines
- Rotor assembly equipment
- Balancing machines
- Dimensional Inspection equipment
- Pumps, Compressors, Exchangers

- Robots
- Remote manipulators

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Extensive **Electronic Equipment** Requirements for Production of Special Nuclear Materials



- Frequency Changers
- Pressure Transducers
- Mass Spectrometers
- Lasers
- Superconducting solenoidal magnets
- High-voltage and high-current power supplies

- Radiation Hardened Cameras
- Radiation Hardened Robots

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Uranium Enrichment and Pu Production Facilities are Expensive

Process	US Investment in Defense Materials Production Facilities*	
Uranium MIning and Milling	$10,000,000	(0.2%)
Feed Materials Production	$256,000,000	(4.6%)
► Uranium-235 Production	$2,343,000,000	(42.4%) ◄
► Plutonium Production	$1,657,000,000	(30.0%) ◄
Heavy Water Production	$163,000,000	(2.9%)
Special Materials Production	$278,000,000	(5%)
Weapon Fabrication and Storage	$821,000,000	(14.9%)
Total	$5,528,000,000	(100%)

*1960 Data from the US Atomic Energy Commission (AEC): John F. Hogerton, ***The Atomic Energy Deskbook***, Prepared under the auspices of the US AEC, Reinhold,1963.

Nuclear Proliferation – The Early Years

- Manhattan Project (WWII) – United States had to make essentially <u>everything</u> needed
- 1st five "weapon states"
  - USA 1945
  - USSR 1949
  - UK 1952
  - France 1960
  - China 1964
    - led to Nonproliferation Treaty of 1970 (NPT)
- Russia and China each developed nuclear weapons in less than five years

Nuclear Proliferation – Slow March Forward

- Nuclear weapons did not spread as quickly as once feared

"I see the possibility in the 1970s of the President of the United States having to face a world in which fifteen to twenty or twenty-five nations may have these [nuclear] weapons. I regard this as the greatest possible danger and hazard."

President John F. Kennedy,
March 31, 1963

More Recent Proliferators

• India	1974
• Israel	?
• South Africa	?
• Pakistan	1998
• North Korea	2006

Several Factors Have Restrained the Rate of Nuclear Proliferation

- Security guarantees
- Treaty on the Non-Proliferation of Nuclear Weapons and other norms against proliferation
- Some countries stopped by external pressure
- Export controls on strategic equipment, materials, and technologies
  - Increase time and resources required
  - Make nuclear weapon programs harder to hide
- **Extensive programs to detect, protect, control, and account for nuclear and radiological materials worldwide**

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Initiatives to Prevent Proliferation and Reduce the Global Risk Posed by Inadequately Secured Nuclear and Radiological Materials

Nuclear Lockdown: 1st Line of Defense

Bolstering Border Security: 2nd Line of Defense

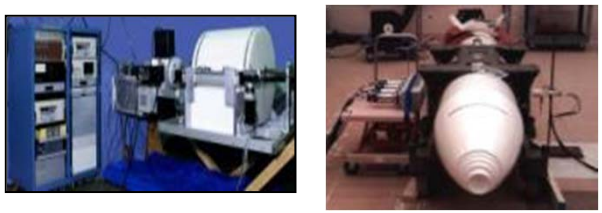
International Export Control

Nuclear Security R&D

International Safeguards & Security

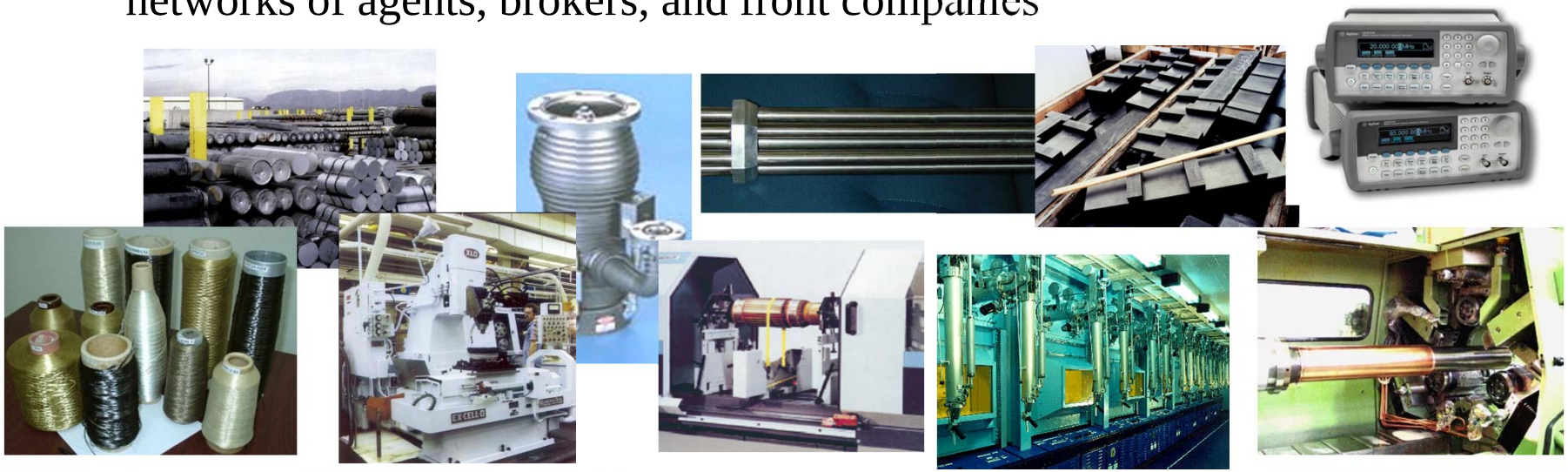
Global Threat Reduction- Convert, Remove, Protect

Verification Technologies



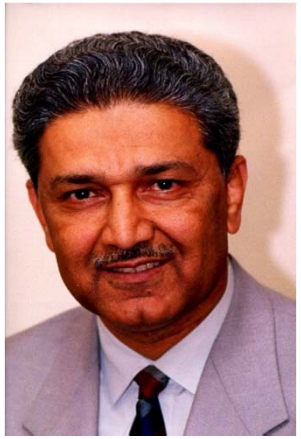
Nuclear Proliferation – Modern Era Strategy

- Proliferation history demonstrates that countries developing WMD programs build indigenous production facilities
- These facilities rely on imports of special equipment, materials, systems, and components
- More recent proliferators obtained these necessary items through supplier networks of agents, brokers, and front companies

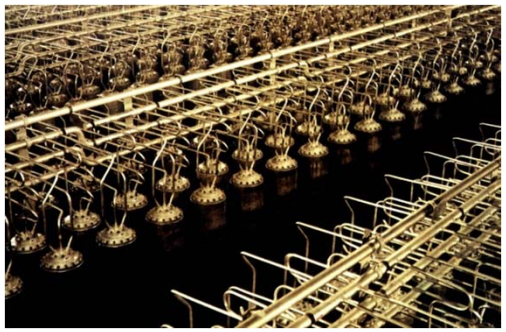


Proliferation Challenges
Case Study – Pakistan

A. Q. Khan – "Father" of the Islamic bomb



- **Stole European plans for gas centrifuge technology (1970s)**
- **Acquired needed commodities for program**
  - Unscrupulous suppliers and brokers
  - Front companies and circuitous buying patterns
  - Bought commodities not yet on export control lists
  - Obtained commodities for weaponization, not just nuclear material production
- **Successfully developed, constructed, and operated uranium enrichment plants**
  - Significant quantities of weapon grade uranium
  - Pakistan – 1998 nuclear test
- **Supplied uranium enrichment technology to other proliferant countries**
  - Designs
  - Equipment



Proliferators Will Aggressively Pursue and Exploit Any Weaknesses or Opportunities

Supplier	Agent/ Broker	Intermediate Consignees	End User
• Some suppliers willing to export illegally, out of ignorance, for economic reasons, or to provide clandestine assistance • **Inaccurate or vague commodity descriptions complicate enforcement**	• **Agents of foreign procurement networks obtain goods, often with circuitous buying patterns, and ship without license** • Disguises or falsifies the final recipient country and/or the end user • Exploit countries with ineffective export controls and other loopholes	• **Diversion in transit and smuggling** • Use of other enterprises and universities to acquire facilities, equipment, technology and training • Cover names and front companies – diversion to unknown ultimate end user	• Utilization of dual-use or uncontrolled commodities to obscure the actual use in a weapons program • False end use statements, connections to activities of concern

Case Study:
Nuclear Reactor Equipment and Zirconium

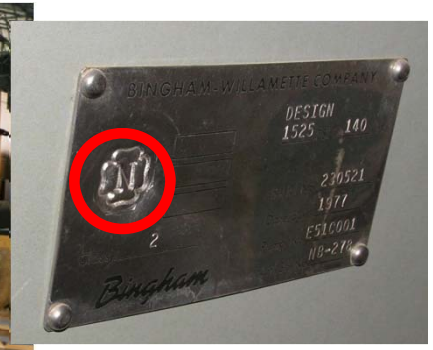
THE CYPRUS WEEKLY
Friday
Oct.19-25, 2001

Cyprus to sell nuke equipment to US
By Charlie Charalambous

In its fight against global terrorism, the government has decided to sell confiscated nuclear equipment to the USA to ensure it doesn't fall into the wrong hands, it was revealed this week.
A Foreign Ministry document submitted to the House Foreign Affairs Committee disclosed that "nuclear reactor plant equipment" and six boxes of Zirconium seized in 1995 would be sold to the Bush administration.
The Customs Department was notified on October 4 that the safest place for the potentially dangerous cache was the United States.

NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011

Recovery of Nuclear Reactor Equipment in Cyprus



RE:ELECTRICAL EQUIPMENT SPARE PARTS

CUSTOM LIMAS

CONTAINER
SEAL #

ITEM	DESCRIPTION	ID #	FEE
1	PRESSURE VALVE	B-6135-3A-1	$ 3,000
1	6" FLOW ELEMENT	S/N H-1322	$ 9,000
1	4" ORIFICE	S/N AH-455	$ 3,500
1	MOTOR PUMP	S/N G-3375	$10,000
1	4" GLOBE CONTROL VALVE	S/N 10078-14-1	$ 6,500
1	1 1/2 " SWING CHECK VALVE	S/N 2069-1	$ 4,000
1	1 1/2" PRESSURE VALVE	S/N G36F061	$ 4,000
	1 1/2" PRESSURE VALVE	S/N G36F062	$ 4,000
	1 1/2" PRESSURE VALVE	S/N G36F063	$ 4,000
1	SOLENOID VALVE	S/N 62620-50	$ 3,000
	SOLENOID VALVE	S/N 6263D19	
1	4" DEZURIK VALVE	S/N G36F059	$ 6,500
1	4" DEZURIK VALVE	S/N G36F058	$ 6,500
1	SOLENOID VALVE	S/N C11F110	$ 2,500
1	1" VALVE	S/N 37-976	$ 3,000
	1" VALVE	S/N 31-976	$ 3,000
	1" VALVE	S/N 32-976	$ 3,000
	1" VALVE	S/N 38-976	$ 3,000
	PUMP PARTS		
1	8" CONTROL VALVE	S/N 10078-7-1	$ 9,000
1	12" STEM PACKING	S/N E6135-3A-1	$ 500
1	GATE VALVE	S/N 205-AH-230	$24,000
1	2" PLUG VALVE	S/N G-36-F061	$ 4,000
1	2" PLUG VALVE	S/N G-36-F062	$ 4,000
	2" PLUG VALVE	S/N G-36-F063	$ 4,000
	4" PLUG VALVE	S/N G-36-F059	$ 6,500
	4" PLUG VALVE	S/N G-36-F058	$ 6,500
	4" PLUG VALVE	S/N G-36-F052	$ 6,500
1	ELECTRIC MOTOR	S/N DNJ 413002	$15,000
1	ELECTRIC MOTOR	S/N HPJ 802217	$15,000
1	PUMP PARTS	S/N AH-121	$ 2,000
1	PUMP PARTS	S/N H-764580	$ 2,000
1	PUMP & MOTOR	S/N 770130-B203	$39,000
1	VALVE STEM PACKING	S/N E6135-2A-1	$ 500
1	PUMP PARTS	S/N C-85-F001	$ 2,000
1	SUPPORT PART	NO S/N	$ 1,000
1	PALLET X-RAYS (13)	1156-3005-18	$13,000
1	ORIFICE FLANGE	G33 N040	$ 1,000
	2 GASKET PLATES		
1	1 PAIR ORFICE ASSEMBLY	G36 N001	$ 2,000
	1 PAIR ORFICE ASSEMBLY	G36 N002	$ 2,000
1	MOTOR/PUMP	NSS-24	$42,000
1	LOW PRESSURE PUMP	S/N 751-8-1343	$23,000
	PUMP PARTS	NO S/N	$ 2,000
1	BOX LITERATURE	NO S/N	$ 500
1	BOX LITERATURE	NO S/N	$ 500
1	BOX LITERATURE	NO S/N	$ 500

Recovery of Nuclear-Grade Zirconium

- Five metric tons stored in a warehouse in Queens; sent to the United States via Germany for ultimate shipment to Iraq – seized at JFK airport by U.S. Customs
- Case involved an extensive sting operation with agents posing as buyers for the Iraqi government ($1.6M offer for the five metric tons)
- Chemical analysis performed in US revealed an extremely low hafnium content (nuclear-grade zirconium)
- Remaining two metric tons of zirconium sent to Cyprus via Amsterdam for ultimate shipment to Iraq – impounded in Cyprus; ultimately transported to United States in late 2001
- Three Greek businessmen arrested on charges of attempting to illegally export nuclear-related materials to Iraq

"That an ordinary warehouse in Woodside, Queens, could be used as a transshipment point for five tons of nuclear-grade zirconium, originating in Ukraine and destined for Iraq, should serve as a wake-up call as to the ease with which such material is available."

James Kallstrom, FBI

Summary

Smuggling, theft, or diversion of nuclear materials could lead to very rapid proliferation or nuclear terrorism

- Acquiring the capability to produce adequate quantities of suitable fissile materials is a long, difficult, expensive undertaking requiring extensive amounts of special equipment and materials.
- If sufficient weapons-useable fissile material were acquired directly, the time-line to a nuclear explosive capability could be very short.
- Wide-ranging programs and initiatives exist to detect, protect, control, and account for nuclear and radiological materials.
- **Vigilance and dedication to the accurate tracking of nuclear materials via NMMSS is integral to our national security.**

Your role in nonproliferation is extremely important!