Part 3

Military use of depleted uranium: Known and suspected DU weapon systems

1. DU and the evolution of hard target weapons

Depleted uranium has been developed for use in armour-piercing ammunition since the 1970's, for sea-to-air cannon and in nuclear bombs. Its first reported combat use by US and UK forces was in anti-tank munitions during the Gulf War in 1991. The use of DU in other conventional weapons systems e.g. in bombs and missiles has rarely been questioned until now, despite comments on **Jane's website** that ***"some guided weapons used depleted uranium to increase the penetration effect"*** and that DU has been used ***"as liners for shaped charge warheads"***. This possibility has either been omitted or denied by the US DoD (except for testing simulated nuclear warheads) and by the UK Government (e.g. 2 Nov & 6 Dec 2001, see Part 2). But the following information strongly suggests that DU is used in several hard target weapons systems.

There is no doubt that a whole new range of hard target warheads are based on some very heavy, **mystery metal** that has been a closely guarded military secret since the 1980's. USAF procurement plans in 1997 give vital clues to recent hard target weapons development based on ***"dense metal" ballast or penetrators*** (see **Tip of the Iceberg** in Part 1). In view of the serious health and environmental hazards associated with DU it is important that past, present and planned hard target weapons are fully and independently investigated for any use of DU. This analysis is a start.

Why should DU be suspected in other weapons systems, especially those with hard target capability? To understand this it is necessary to appreciate the very unusual **physical properties of Uranium 238,** see **Section 2**.

It is also necessary to appreciate **strategic threats** e.g. suspected production of chemical, biological and possibly nuclear weapons in Iraq, Serbia and other countries in the 1990's. Such installations, together with strategic command centres, are likely to be in heavily protected underground facilities. These issues were identified in the US **Hard or Deeply Buried Target Defeat Capability (HDBTDC) programme.** See the FAS website at: http://www.fas.org/man/dod-101/sys/smart/hdbtdc.htm

A key issue is to understand what **new weapons technologies** have been developed in the last 15 years to defeat these hard or deeply buried targets without resorting to nuclear weapons. Anti-tank munitions are an important tactical requirement. But the capability to destroy chemical, biological or command centre targets is a strategic defence issue in the HDBTDC programme. High priority has been put on warhead development to contain these strategic threats. Several **new weapons concepts** have evolved in response to these requirements. These are described in **Section 3.**

Full DU risk assessment requires knowledge of potential sources of contamination (potential hazards) and correlation with epidemiological analysis of exposed populations (see Part 4). The current benchmark for political debate and published health research concerning DU is based on **known DU weapon systems** i.e. armour plating and armour-piercing anti-tank munitions. These are described in **Section 4.**

But when strategic requirements for a new generation of hard target guided weapons are combined with the physical properties offered by depleted uranium, we have the basis for radically different systems. These requirements provide the basis for identifying **specific warheads** likely to contain DU and **the guided weapons systems** designed to deliver use them. These are listed in three groups:

- **Section 5** covers hard target versions of **smart or guided bombs.**
- **Section 6** covers hard target versions of **cruise missiles** and
- **Section 7** explores suspected DU use in **sub-munitions,** cluster bombs & SSB's.

In the Afghan war there has been relatively little need to use known (anti-armour) DU weapons except in AC-130U ground support operations. However there has been widespread use of guided bombs and cruise missiles on hundreds of hard-target locations, probably in larger quantities than any other conflict in the last 20 years.

Establishing whether or not these new guided weapons contain DU, and if so exactly how much, is essential to evaluating potential levels of DU contamination and hence health hazards in Afghanistan. The potential quantities of DU contamination per target between A10 strikes in the Balkans and guided weapons targets in Afghanistan can be seen in Figure 1.

2. Properties, advantages and hazards of DU for military use

Depleted Uranium is a dense metal 1.7 times heavier than lead, produced as the major by-product of processing Uranium ore to extract U235 for the nuclear industry **and** of re-processing spent nuclear reactor rods. It is mainly composed of **Uranium 238** (99+%), with variable levels of other radioactive materials including **U234**, **U235**, **U236** and **Plutonium** depending on the reliability of the extraction process and what other materials have been recycled with it.

Depleted uranium has five advantages for military applications:

- **Uranium 238** is **a very heavy, dense metal**. When used to upgrade existing weapons systems this means that the same weight of warhead can be half the cross-section area of devices previously made with steel i.e. warheads can be much thinner, **doubling their penetration effect** (see weapons upgrade concepts in **Tip of the Iceberg**). It is 2.1 times heavier than Nickel or Cobalt, 2.4 times heavier than Iron and 4.2 times heavier than Titanium. The density of U238 is approximately 19.0 compared to 19.25 for Tungsten (or 19.3 for Gold). Weapons systems using the high density of Tungsten or DU are known as **kinetic energy weapons**. Physical properties of DU and other metals can be checked at: http://www.webelements.com/webelements/elements/text/periodic-table/phys.html
- **Uranium 238** is **a very hard metal**, the second hardest common metal to Tungsten (apart from rare metals like Osmium). It is 2 times harder than Titanium and 3 times harder than Iron (levels depend on the type of hardness being tested - Vickers hardness used here). Its hardness is increased in alloy form (e.g. with 0.75% Titanium in anti-tank penetrators). Manufacturing processes e.g. heat treatment and forging, determine DU's strength and fragmentation qualities.

- **Uranium is pyrophoric** i.e. it burns fiercely in air igniting at temperatures over 500 degrees Celsius and burning at some 2000 degrees. This makes it valuable as an **incendiary weapon** e.g. to ignite fuel or munitions in tanks and potentially highly effective against other targets where great heat is an advantage e.g. underground ammunition or fuel stores, aircraft hangers and biological or chemical weapons facilities.

- **Uranium 238** is **easier to manufacture** than Tungsten (Wolfram) which is 1.75 times harder and has a much higher melting point (U = 1132 ^{o}C, W = 3422 ^{o}C).

- It is **cheaper and more available** than Tungsten since the world nuclear industry has over a million tons of waste DU to dispose of. http://www.uxc.com/review/ux_prices.shtml

The main hazards of DU are health and safety issues:

- Risks of **fire**. DU can ignite at relatively low temperatures (500 C).
- **Heavy metal toxicity**: Uranium is a heavy metal and its oxides are reported to be of similar toxicity to Arsenic oxide, particularly affecting the renal system. This may not appear significant from small inhaled quantities but could be serious in acute exposure to explosion dust and debris with a high load of DU oxides entering nose and throat and swallowed, or prolonged exposure in a contaminated environment.
- Risks of **radioactive contamination** by inhaling DU oxide dust and ingesting it from dust in the mouth, in water or in food. DU burns into a very fine black dust or 'aerosol' with a combination of soluble and insoluble Uranium oxides. Larger particles may coat the immediate target area with what looks like soot. But 60%+ are less than 1.5 microns, widely dispersed by wind and small enough to remain suspended in the atmosphere in smog-like conditions. Airborne oxides may be captured in rain or snow and re-suspended in hot weather. DU contamination was recorded up to 25 miles away from one manufacturing site in the USA.

DU's radiation hazards are its most controversial feature. Pure U238 emits alpha-radiation - high energy but very short range (a few millimetres) plus traces of Beta and Gamma from the Thorium and other "daughter" isotopes released as it decays.

For military purposes this low-level radiation appears to be low risk for external exposures e.g. when handling DU in its metal form (e.g. as shells or armour) provided gloves are worn. But some spent munitions have been reported with higher levels of radiation possibly due to inconsistent processing and higher contamination with U235 and other isotopes. DU quality control and contamination (isotopic mix) is likely to vary significantly by manufacturing date, process and country of origin.

The greatest hazard is when soluble and insoluble Uranium oxides are inhaled into the lungs. Particles migrate into the lymph and blood systems, bones and reproductive organs. Alpha radiation will permanently irradiate adjacent tissue. See research on **health effects of Low Level Radiation** at: http://www.llrc.org/health/healthpage.htm

Adverse health effects will depend on **exposure level** - a combination of the **quantity** of DU oxide dust inhaled or ingested, **frequency** and **duration** of exposure. Most DU research to date has assumed low dose exposure for fit troops from small and medium calibre weapons (from 30 to 120 mm) weighing from 275 grams up to 4.5 kilograms per penetrator. However if DU is used in much larger quantities - in warheads weighing 300 kg to 2 tons - then humans within several hundred metres may suffer severe contamination and acute health effects. Civilians living in DU targeted areas are vulnerable to ongoing contamination. These wider effects need new analysis.

3. New weapons technology - known and suspected DU applications

Armour plating

Due to its hardness DU has been used in modern armoured vehicles for at least a decade. In the CDI Defense Monitor (Vol. 6, 1999) - ***Depleted Uranium - a necessary evil?*** They point out that "in the Gulf War Iraqi tank shells failed to penetrate any DU-reinforced parts of U.S. tanks". See http://www.cdi.org/dm/1999/oct99dm.pdf

Further descriptions of the use of DU in defensive armour and in DU 120 mm anti-armour shells, are available in **Depleted Uranium - the truth & nothing but the truth, by** Mike Sheheane in **Armor** magazine. Go to index, Back Issues, July-August 2000 at: http://knox-www.army.mil/center/ocoa/ArmorMag/index.htm

Projectile penetrators (non-explosive)

The only publicly acknowledged DU munitions are non-explosive, armour-piercing **penetrators**. Nominal sizes range from 20, 25 and 30 mm rounds designed for rapid fire cannons up to 105 and 120 mm penetrator rounds for tanks. See Section 4 for specific ammunition types.

Some DU penetrators are like thin darts. Because they are thinner than the calibre of the gun firing them tank rounds are held by a sabot (or washer) which is discarded as they leave the gun barrel. In 30 mm rounds the 16 mm DU penetrator is held inside an aluminium jacket which is shed on hitting the target. The penetrator contains DU alloyed with 0.75% of titanium. They may be mixed with other shells in rapid fire applications.

On impacting the target the penetrator's high kinetic energy is converted into heat, igniting the point which then burns or melts its way through the target's armour. The penetrator may pass straight through the vehicle, shatter into shrapnel or burn inside it. The larger 120 mm DU penetrators, shells or warheads are likely to create intense heat, igniting munitions and fuel. Anti-armour penetrators do not contain explosive - they ignite spontaneously.

The immediate hazards of these DU munitions are to casualties inside target vehicles who may suffer shrapnel wounds, very severe burns or even be carbonised by the fierce heat of burning DU. The ongoing hazard is radioactive contamination of the target and immediate area by DU oxide dust - a risk for repair and recovery personnel, and for civilians tempted to enter a burned out vehicle destroyed by DU e.g. children.

Unitary penetrators in hard target bombs and missiles

A major tactical issue in battlefield situations is defeat of **hard or deeply buried targets** e.g. command bunkers, fuel and ammunition stores, aircraft hangers with reinforced roofs etc. Since the 1980's a variety of heavyweight warheads have been developed in various bomb and missile systems to defeat these "hard targets".

Several different hard target warhead technologies have evolved. Some use focused explosives (see ***shaped charge penetrators*** below). But for very thick targets (e.g. 100 feet of earth or 10-20 feet of concrete) **new design concepts and technology** were required and evolved in the 1990's.

This evolved from the success of prototypes of the 2 ton **GBU-28 Bunker Buster** bomb - artillery gun barrels packed with explosives and fitted with a laser guidance system. This system has subsequently been developed into the **BLU-113** warhead. It may also have been influenced by Maverick G warhead developments in the late 1980's

The **Advanced Unitary Penetrator** concept was described in the 1997 USAF Concept plan (see Tip of the Iceberg). ***"The warhead would either be designed with a dense metal case or dense metal ballast to increase penetration"***. Doubling the effect of older steel bombs or warheads requires a very heavy metal. Only tungsten or depleted uranium or a combination can offer double the density of steel.

Some of these penetrators are also designed with special missions in mind e.g. destruction of suspected underground chemical or biological weapons facilities. This is explained in the **Hard or Deeply Buried Target Defeat Capability programme** (HDBTDC). "Agent neutralization will require key data needed to understand the collateral effects consequences of strikes against chemical and biological weapons-related facilities." A powerful **incendiary** warhead could be effective in neutralising biological and some chemical agents.
See FAS at: http://www.fas.org/man/dod-101/sys/smart/hdbtdc.htm

The **structure of unitary penetrators** is explained for several weapons systems on the FAS website e.g. for the 2000 lb **GBU-24 Paveway III** guided bomb.

> "The **Advanced Unitary Penetrator** [AUP] hard target penetrator features an elongated narrow diameter case made of a tough nickel-cobalt steel alloy called Air Force 1410. With the official designation of BLU-116, and designated the GBU-24 C/B (USAF) and GBU-24 D/B (Navy), is designed to provide at least twice the penetration capability of existing BLU-109 2000-pound bombs.
>
> Penetration capability is directly proportional to the warhead's sectional density - its weight divided by its cross section. **The AUP maximizes sectional density by reducing the explosive payload and using heavy metals in the warhead case**. Lower explosive payload will diminish dispersion of NBC agents to help reduce collateral effects. The AUP will retain the carriage and flight characteristics of the BLU-109, and it will be compatible with the GBU-24, GBU-27, and GBU-15/AGM-130 series of precision-guided bombs. Thus, the AUP will be capable of delivery from a wider inventory of aircraft, including stealth platforms, than the BLU-113/GBU-28. See FAS: http://www.fas.org/man/dod-101/sys/smart/gbu-24.htm

Advanced penetrators use delayed action **Hard Target Smart Fuses** that do not detonate until the weapon has reached a void or gone as deep as it can e.g. cutting through several floors of a building and exploding in the basement. Warheads come in various sizes - 250, 500, 1000, 2000 lbs up to the 4400 lbs BLU-113. These approximate weights include explosive and outer casing. The dense metal ballast or case may represent 50-70% of warhead weight depending on the system involved, plus additional weight of airframe, guidance and propulsion. See FAS reports. For incendiary effects DU alloy fragmentation properties would enable optimum ignition.

Boosted penetrators

A variation on the unitary penetrator concept is a **boosted penetrator**. The basic concept of a high-density warhead is boosted by a wraparound rocket motor or rear facing explosive charge. These may double the impact speed and kinetic energy of the warhead in addition to the advantage of using thinner, high density penetrators.

A rocket booster is used in the BLU-107 Durandel runway breaking bomb. The composition of the explosive penetrator warhead is not known. The 1997 Concept plan referred to other boosted penetrator systems from 250 - 2000 lb.

Shaped charge warheads

Shaped charge technology dates back to World War 1. Shaped charges increase power by focusing explosives in one direction e.g. by containing them with a conical liner. In February 2001 Jane's website said that DU was also used as "liners in shaped charge warheads" (see Tip of the Iceberg). This reference is no longer available but was sufficient to extend these investigations to include shaped charge weapons.

A wide variety of guided weapons use "**shaped charge**" technology. These range from Maverick and Hellfire missiles to torpedoes, sub-munitions in cluster bombs and the first stage of BROACH MWS warheads.

> "A shaped charge is a **concave metal hemisphere or cone** (known as a liner) backed by a high explosive, all in a steel or aluminium casing *. When the high explosive is detonated, the metal liner is compressed and squeezed forward, forming a jet whose tip may travel as fast as 10 kilometres per second. Shaped charges were first developed after World War I to penetrate tanks and other armored equipment. Their most extensive use today is in the oil and gas industry where they open up the rock around drilled wells." See http://www.llnl.gov/str/Baum.html

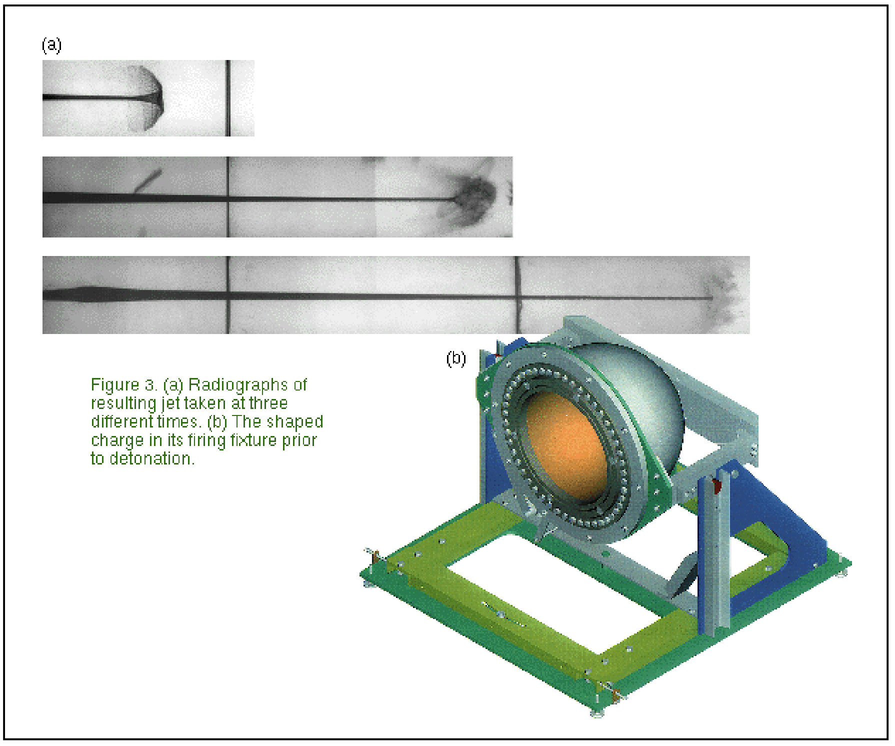


Figure 3. (a) Radiographs of resulting jet taken at three different times. (b) The shaped charge in its firing fixture prior to detonation.

Photo © Baum

* DU seems a logical metal for the outer casing. Its high density would offer maximum inertia to focus the blast and its strength can be varied according to the alloy mix used e.g. titanium, niobium or molybdenum. The inner (typically cone shaped) shaped charge liner can be made of a variety of metals e.g. Copper, Molybdenum and according to Jane's previous reference Depleted Uranium. These have similar melting points so DU (1132 ^{o}C) may be interchangeable with Copper (1085 ^{o}C). The very high melting point of Tungsten (3422 ^{o}C) seems less suitable for a shaped charge liner. The quantity of DU involved may range from a few kilograms up to 250 kg in larger warheads e.g. as suspected in the first stage of the BROACH warhead.

The WISE website lists a number of DU manufacturing organisations on its website at http://www.antenna.nl/wise/uranium/dfac.html#AMMFAB . These include Primex and Alliant. The **Primex** website does not mention its DU products but shows a picture of Copper shaped charge liners at http://www.primextech.com/warhead.html

Photo © Primex

The **Manufacturing Sciences Corporation** website (a subsidiary of BNFL) show a range hemispheres, cones and penetrator-sized rods in their **Products from Depleted Uranium** at http://www.mfgsci.com/metprod.html#du . Several of these "safe, useful products" look remarkably similar to shaped charge warhead components in the two previous pictures.

Photo © Manufacturing Sciences Corporation

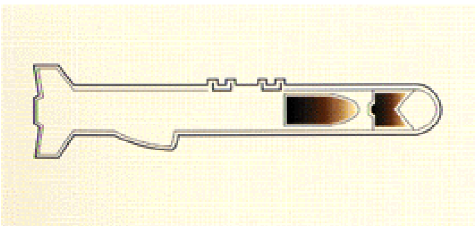
"Since 1985, MSC has converted over 6 million pounds of depleted uranium into more than 70,000 safe, useful products. MSC has performed this work under a radioactive material operating license issued by the State of Tennessee under NRC guidelines. MSC performs its depleted uranium operations in a special controlled area that is continuously monitored and where the air is drawn through high energy filters to remove any airborne dust and particles."

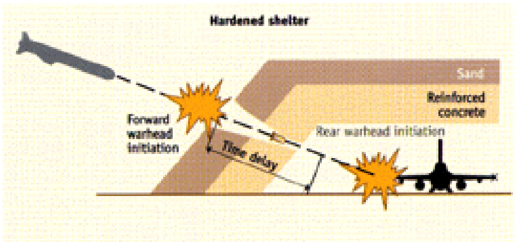
Shaped charge liners are also shown in the diagram of BLU-97/B anti-armour bomblets in the CBU-87B Combined Effects Munition (cluster bomb), see page 91 and FAS illustrations at: http://www.fas.org/man/dod-101/sys/dumb/cbu-87.htm and the CBU-97 at http://www.fas.org/man/dod-101/sys/dumb/cbu-97.htm .

Multiple Warhead Systems (MWS or BROACH)

These combine shaped charge and unitary penetrator technologies e.g. in the BROACH warhead developed for the AGM-86D, AGM-154C and Storm Shadow. One or two shaped charges are at the front of the warhead and loosen up the target on initial impact. A unitary penetrator with delayed action fuse follows through the loosened structure and is detonated inside. Developed for 1000 and 2000 lb warheads, possibly more. See **Defeat of High Value Targets** at: http://www.thomson-thorn.co.uk/activities/mws.htm

> "A multi-warhead system (MWS) achieves its results by combining an initial penetrator charge (warhead) with a secondary follow-through bomb, supported by multi-event hard target fuzing. The outcome is a warhead and fuze combination that provides for the defeat of hardened targets more than twice that achievable for equivalent single penetrating warhead types, at an equivalent weight and velocity. The warhead technology can be scaled and configured for a variety of weapon payload and targets requirements."





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Diagrams comparing the unitary penetrator and MWS options for the AGM-86C/D are available at : http://www.fas.org/man/dod-101/sys/smart/agm-86c.htm or see section 6 below.

On 6 December 2001 UK Government defence spokesman Mr Ingram denied that DU is used in the BROACH MWS warhead systems, see Hansard quote on page 68 and below.

> "The only dense metal contained in the BROACH MWS is a tungsten-based alloy. No other dense metal is or has been used in its development or testing."

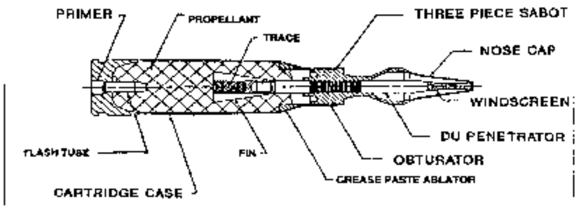
This seems a most improbable reply since Tungsten is likely to have too high a melting point for the shaped charge liner in the first stage. And Tungsten does not offer the potential incendiary effect needed if the second stage warhead is to achieve the US requirement for neutralising chemical and biological warfare targets. The BROACH MWS warhead concept was originally developed to meet US specifications for upgrading the AGM-86D and JSOW AGM-154C, refer data in Tip of the Iceberg on page 15.

4. DU ammunition and armour-piercing weapons

This is the one category of DU weapons that is openly acknowledged by the US and UK governments. These are mostly non-explosive projectile penetrators (see 2.2. above). They provide a reference point for comparing the effects other types DU munitions. Main armour-piercing munitions are:

20 mm Phalanx ground-to-air anti-missile shells. Used by several navies including UK and Israel. High density enables low calibre / high velocity. Recent production converted from DU to Tungsten despite price, possibly due to fire risks of stored ammunition. Health and environmental risks low.

25 mm ammunition includes the **M791 APDS-T** (Armour Piercing Discarding Sabot with Tracer) shell for the Bradley Fighting Vehicle against light armour. "All rounds are interchangeable with the M242 Bushmaster gun, the KBA B02B automatic cannon, the GE525 (GAU-12/U) Gatling gun, and other NATO-qualified systems." See FAS: http://www.fas.org/man/dod-101/sys/land/m791.htm **The M919** 25mm Armor-Piercing, Fin Stabilized, Discarding Sabot with Tracer (**APFSDS-T**) shell has longer range. http://www.fas.org/man/dod-101/sys/land/m919.htm .



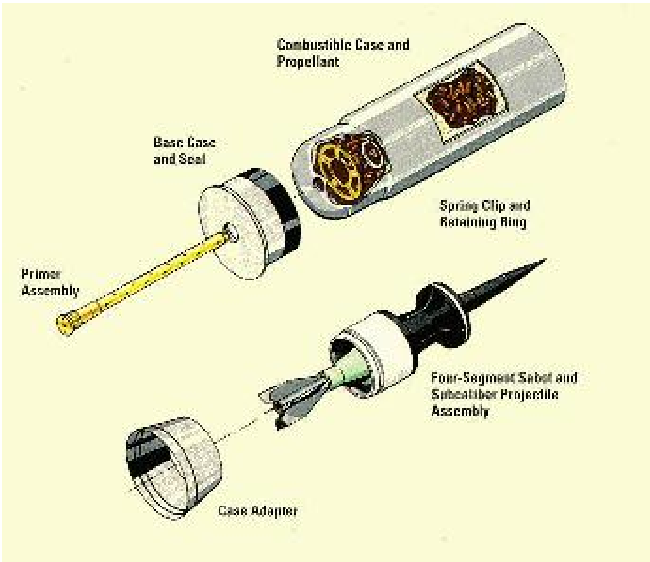
Picture FAS

The **AC-130** flying gunship http://www.fas.org/man/dod-101/sys/ac/ac-130.htm used extensively for ground support missions in Afghanistan is equipped with the 25 mm **GAU-12** Gatling gun (1,800 rounds per minute) with DU ammunition for use against armoured targets. http://www.fas.org/man/dod-101/sys/ac/equip/gau-12.htm

30 mm PGU-14/B API (Armour Piercing Incendiary) round "has a lightweight body which contains a sub-calibre high density penetrator of Depleted Uranium (DU). In addition to its penetrating capability DU is a natural pyrophoric material which enhances the incendiary effects. Each DU projectile contains 0.66 pounds (0.3 kg) of extruded DU, alloyed with 0.75 weight percent titanium". Widely used in the Gulf war and 30,000 rounds (9 tons) declared in the Balkans War, mainly from A10 Warthog "Tankbuster" aircraft. These were the DU munitions investigated by UNEP in the Balkans in November 2000. See FAS at http://www.fas.org/man/dod-101/sys/land/pgu-14.htm and the "high density" penetrators (DU not mentioned) on the Alliant Techsystems Inc website: http://www.atk.com/defense/descriptions/products/medium-cal-ammo/gau-8.htm


Photo © Alliant Techsystems Inc.

120 mm M829A 2/3 APFSDS-T armour piercing shells for the US Abrams tank. "The 120mm ammunition system equips the MIE1 (Abrams) tank with a 120mm main armament. It consists of a family of kinetic energy (KE) rounds and a family of high explosive anti-tank (HEAT) rounds. The KE rounds use a high length over diameter ratio subcaliber projectile with a depleted uranium (DU) fin-stabilized rod as the penetrator element." Cartridge weight 41 lbs (DU penetrator not specified but perhaps a third of this - 13 lbs / 6 kg). http://www.fas.org/man/dod-101/sys/land/120.htm



Picture FAS

"Army test data shows that between 10 and 70 percent of the mass of a DU penetrator oxidises on impact. Thus one 120 mm M829A round would create roughly 1-3 kg (2-7 lb) of depleted uranium dust.". (refer Don't Seek, Don't Find, page 20, available at http://www.miltoxproj.org/DU/IOM-cover.htm

Other non-explosive DU penetrator ammunition is known to be manufactured in other countries e.g. the **120 mm CHARM** armour piercing shell for the UK's Challenger tank, and rounds produced by Russia, Israel and China. Different calibre rounds are adapted for a range of other weapons systems e.g. helicopters, small fighting vehicles and field guns (refer FAS and Jane's websites).

Other armour piercing weapons include **guided missiles** and some **sub-munitions** (see section 7). These have much smaller warheads that the hard target guided bombs and cruise missiles described in the next two sections.

But since they all employ heavy metal penetrators or shaped charge warheads it is very likely that some versions rely on Depleted Uranium as a major component in their warheads. DU investigation is needed on at least three missile systems: TOW, Hellfire and Brimstone.

The combined kinetic energy and pyrophoric effects of DU make it a logical option in armour-piercing missiles e.g. the **M220 TOW** fly-by-wire anti-tank missile. "Current versions are capable of penetrating more than 30 inches of armour, or 'any 1990s tank,'. See FAS at http://www.fas.org/man/dod-101/sys/land/tow.htm