TOW is the most widely distributed anti-tank guided missile in the world with over 500,000 built and in service in the U.S. and 36 other countries."

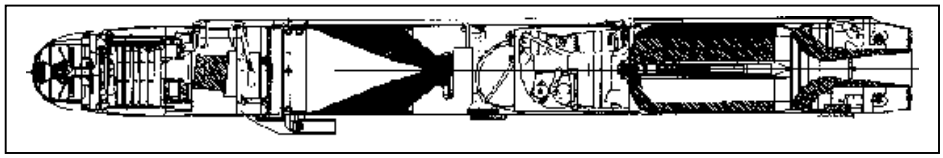
> "(In the Gulf War) the lethality of the TOW missile was proven beyond doubt during the 100-hour ground campaign when one of the antitank munitions fired by US troops went right through the tank it was aimed at and penetrated another tank parked next to it. Another TOW went through a six foot dirt berm and knocked out an Iraqi armored personnel carrier on the other side."

These descriptions are very similar to reports of 120 mm DU tank rounds.

TOW has several warhead options, weight 12 kg, at least one reported to use DU. "**BGM-71C Improved TOW (ITOW)** The Improved TOW (ITOW) was delivered in 1982. This missile has a 5-inch diameter warhead, and includes **an extended probe** for greater standoff and penetration." Is this probe a DU penetrator?

In the late 1980s the **TOW 2A** was developed and in 1991 **TOW 2B (1991)** had a new double (multi-stage?) appears to have no explosive fill in its double warhead.

Other anti-tank missiles e.g. the **AGM-114 Hellfire** and its **Brimstone** variant use **shaped charge warheads**. If DU liners are used in these warheads this would increase their incendiary effects and might explain their names. See FAS at: http://www.fas.org/man/dod-101/sys/missile/agm-114.htm



↑ Guidance ↑ Shaped charge warhead ↑ Rocket motor

Picture FAS

No doubt there are several other anti-amour missile systems with similar performance and design options. Though they may deliver relatively small DU loads per target (10+ kilograms) they have been used in significant numbers during and since Operation Desert Storm, potentially adding to DU contamination in target areas

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5. 'Smart' or guided bombs (see also Figure 1, page 89)

Smart bombs have been developed by adding fins and guidance units (e.g. JDAM) to "dumb" (free-fall) bombs. Dumb bombs usually have prefixes like BLU e.g. the 2000 lb BLU-109. A smart bomb usually has the pre-fix GBU (Guided Bomb Unit).

The following hard target bombs have been upgraded to use **Advanced Unitary Penetrators** with "dense metal" ballast or casing warheads (see Tip of the Iceberg and 2.3 above). Variants on the AUP concept e.g. the BLU-116 are designed to by fully interchangeable with earlier BLU-109 or 110 bombs. Unless the warhead is specified as well as the guidance kit it is not possible to know which has been used in bombing reports referring generally to GBU-15, 24, 31, 32 etc. Details for each weapon are available via the **FAS Smart weapons index** at http://www.fas.org/man/dod-101/sys/smart/index.html

- **GBU-15** GPS guided bomb (2000 lbs) BLU-109 or upgraded with BLU-116 penetrating warhead.
- **GBU-31 JDAM** (2000 lbs) BLU-109 or upgrade.
- **GBU-32 JDAM** (1000 lbs) BLU-110 or upgrade.
- **GBU-24/B Paveway III** & **27B Penetrator Weapon**, both with upgraded BLU-109 (2000 lbs) warheads. See FAS website (above) & Raytheon website (below)
- **GBU-28 or GAM-37** (4650 lbs) **Bunker Busters** with upgraded BLU-113 hard target penetrator warhead.

The **JDAM** (Joint Direct Attack Munition) programme "was certified as operationally capable on the B-2 in July 1997. Limited Initial Operational Capability was achieved on the B-52 in December 1998." The bolt on GPS guidance kits cost approximately $18,000 each. See http://www.fas.org/man/dod-101/sys/smart/jdam.htm for JDAM details including the following extracts:

> "The Advanced Unitary Penetrator (AUP), a candidate to be integrated with a GBU-31 guidance kit, is a 2000 lb. class penetrator warhead intended as an upgrade/replacement for the BLU-109 warhead in applications requiring increased penetration. The AUP is designed to provide increased penetration capability over the BLU-109 warhead while maintaining the same overall weight, mass properties, dimensions, and physical interfaces associated with the BLU-109 warhead. This concept integrates the AUP warhead with the GBU-31, the JDAM tail kit for 2,000 lb class warheads."

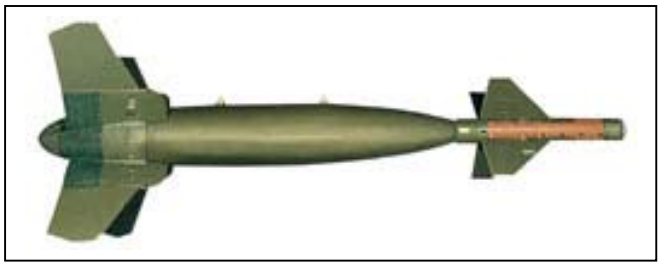
On 12 October 2001 the **Centre for Defence Information** (CDI) Action Update reported that 500 JDAM bombs were used in the first 5 days of the Afghan war. Bombing reports at http://www.cdi.org/terrorism/actionupdate.cfm

On 5 December a 2000 lb **GBU-31 JDAM** was dropped within 100 metres from US and Afghan alliance troops. Sadly 3 troops were killed. It is hoped for the survivors that this was an old, non-DU version. Otherwise they may have been exposed to intense heat and acute DU oxide dust inhalation.

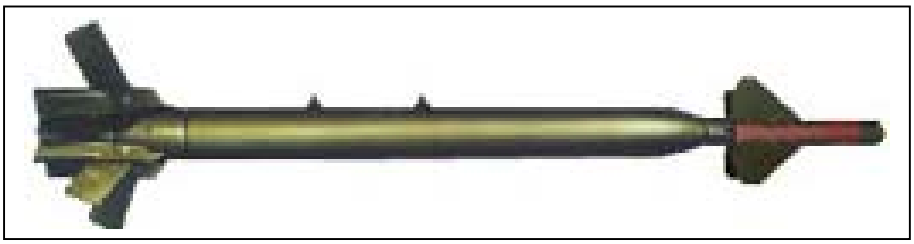
"Several reporters and photographers complained that they were denied permission to watch or take pictures " not standard Pentagon practice" (Intl Herald Tribune, 6 Dec). If DU was involved they may have suffered severe burns or charring. The survivors may have suffered severe inhaled DU dust contamination putting them at high risk of developing Leukaemia, suffering renal problems or potential defects for future children as suffered by veterans exposed to DU oxide dust in previous operations. Their future

medical condition should be of serious concern to the public and military authorities as potential indictors of the health hazards of high load DU weapons.

For details and pictures of the **GBU-24 Paveway III** (2000 lb), and **GBU-28 or 37** (4400 lb warhead) **Bunker Buster** guided bombs see also the **Raytheon** website at: http://www.raytheon.com/es/esproducts/dsspvwy/dsspvwy.htm . .



GBU-24B Pictures © Raytheon



GBU-28 Bunker Buster

These **are highly suspected of containing DU as the main ballast in their penetrators** possibly alloyed with small quantities (less than 1%) of other metals like Titanium. Their have been used in operation Desert Fox (Dec 98), the Balkans War and Afghanistan. Operations may have involved both old and new versions to run down old stocks and test new ones. See FAS reports via the smart bomb index or direct at http://www.fas.org/man/dod-101/sys/smart/gbu-28.htm .

The operation of the **GBU-28 Bunker Buster** is illustrated in a graphic for USA Today at http://www.usatoday.com/graphics/news/gra/gbuster/frame.htm .

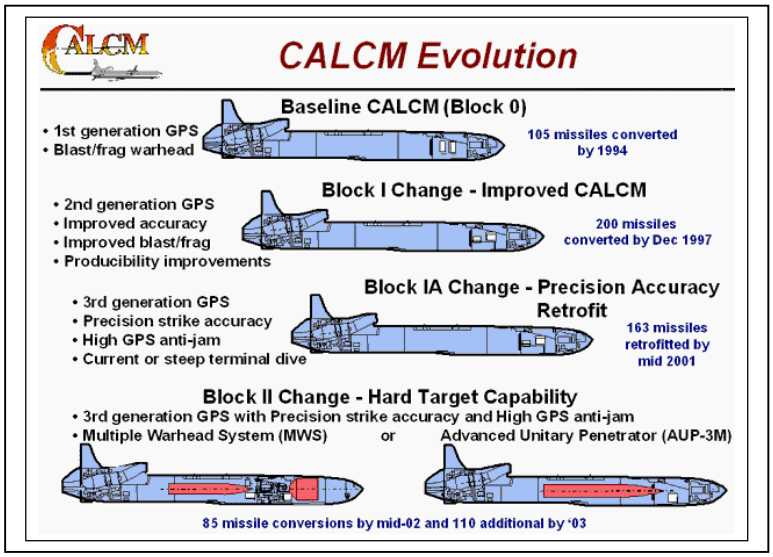
The GBU-28 weighs 4650 lbs including a 4400 lb warhead with 630 lbs of explosive. "The composition of the rest of the warhead is classified". They cost $145,600 each. Discounting the cost of guidance unit, fuse and explosives (say $25,000) then the warhead material would cost about $32 per lb. Metal traders can calculate whether this is more likely to be tungsten or depleted uranium.

These smart bombs represent a large proportion of the ordnance used in the Afghan War. From CDI reports it is estimated that at least 500 tons of smart bombs and cruise missiles were used in the first month of the war. The extensive bombing of the Tora Bora region would have mainly involved hard target weapons so in total over 1000 tons of them may have been used in the Afghan. If these are mostly DU based munitions they may represent 2-3 times the tonnage of DU declared in the Gulf War in Iraq.

6. Hard Target Cruise missiles (see also Figure 1, page 89)

Hard target versions of cruise missiles with new Advanced Unitary Penetrators or Multiple Warhead Systems are highly suspected of containing DU. See the **FAS** index at: http://www.fas.org/man/dod-101/sys/smart/index.html Key systems are:

AGM-86D CALCM (Conventional Air Launched Cruise Missile) . The CALCM is a long range cruise missile (600+ miles) originally designed for nuclear weapons. Old stocks have been converted to conventional blast or penetrator warheads over the last 3 years. 30-50 86C's were used in the Balkans War. See FAS report for development history and diagrams of warhead options at:
http://www.fas.org/man/dod-101/sys/smart/agm-86c.htm



Picture FAS
© Boeing ?

Uses a Lockheed Martin AUP-3M penetrator (1200 lbs*) see FAS and Boeing sites. Conversion of 85 from previous nuclear to new hard target warheads. 35 x 86C's were tested in Desert Fox (Dec 98). Others used in the Balkans War. Competition between Lockheed Martin and BAE-RO BROACH warheads from mid-98.

Prototype testing for both warheads suspected during Balkans War. Upgrade contract for 50 AGM-86D confirmed 29 Nov 1999 for delivery by mid-2001. Lockheed option confirmed 2 Dec 99 (see Boeing new releases). **Several different warhead weights are reported**. The AGM-86C Block II upgrade carries a 3,000-lb PBXN-111 Blast Fragmentation Warhead (FAS). The 1998 Boeing BROACH tests refer to a 900 lb warhead (Boeing 11 June 1998).

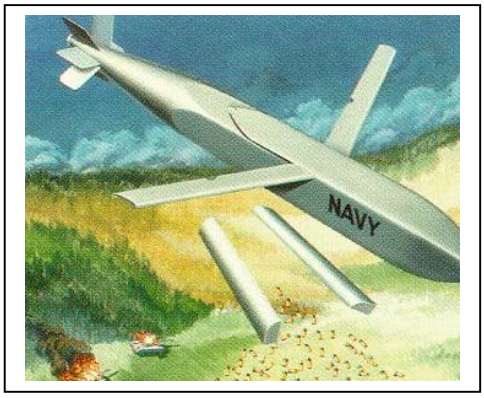
The FAS description of the AUP-116 2000 lb penetrator notes "a proposal to replace the current CALCM warhead with an AUP warhead provides 2.5 times BLU-109 penetration capability." This would be consistent with plans to standardise warhead options across a variety of guided bomb and missile delivery systems. The Lockheed AUP-3(M) is quoted as 1,200 lb (Boeing 2 Dec 1999). 86D test reported Nov 29, 2001.
http://www.boeing.com/defense-space/missiles/calcm/calcm.htm

AGM-130C A powered version of the GBU-15 guided bomb with a rocket motor for extended range. TV or infrared seeker guidance. The 130C adapts the munition to a 2,000 lb penetrating warhead (BLU-109/B or BLU-116), one of the biggest AGM's.
See http://www.fas.org/man/dod-101/sys/smart/agm-130.htm

AGM-142 Raptor (Hav Nap) One of the earliest and largest hard target cruise missiles, developed by Israel in the 1980's. Its **I-800** penetrator warhead (770-800lbs) was added soon after the Gulf War. The US produced version is designated AGM-142. Used in the Balkans and in the recent Afghan bombing as supplies of US AGM-86D ran low. See FAS at http://www.fas.org/man/dod-101/sys/smart/agm-142.htm

AGM-142
Picture © FAS

AGM-154C JSOW see FAS and Raytheon sites. The BAE-RO BROACH warhead was evaluated in1998 for the hard target version C. It appears that this warhead was chosen for recent production. http://www.fas.org/man/dod-101/sys/smart/agm-154.htm



AGM-154C
Picture © FAS

BGM-109 Tomahawk (Unitary & Penetrator Versions). Tomahawk has evolved through several versions including the **conventional land attack missile (TLAM/C),** It is not clear whether earlier unitary warhead versions of Tomahawk contained DU munitions. This was denied by the US Navy in 1999. However according to FAS "the **Tomahawk Baseline Improvement Program (TBIP)** will also enhance its hard target penetrating capability beyond current weapons systems. These missiles are expected to enter service around 2000."

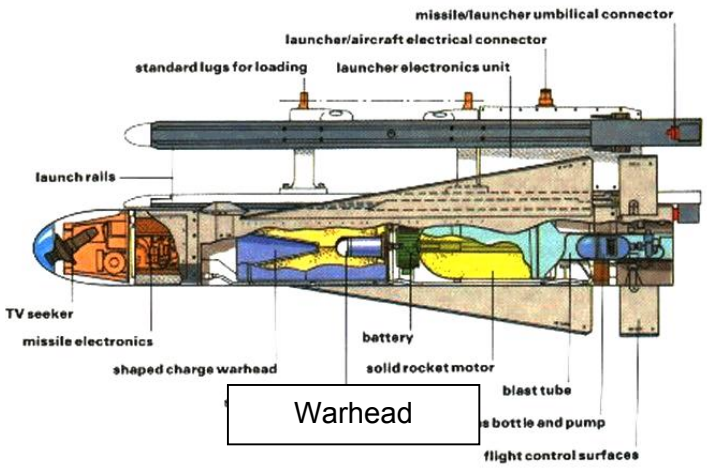
"On 27 May 1999 Raytheon was awarded a $25,829,379 undefinitized cost-plus-incentive-fee/cost-plus-fixed-fee, ceiling amount contract for the modification of the Tactical Tomahawk missile to the **Tactical Tomahawk Penetrator Variant** configuration as part of the Second Counter-Proliferation Advanced Concept Technology Demonstration. The Tactical Tomahawk missile will be modified to incorporate the government-furnished penetrator warhead and the hard-target smart fuze." Quotes from FAS at http://www.fas.org/man/dod-101/sys/smart/bgm-109.htm

Tomahawks can carry a 1000 lb warhead. This could be the AUP-1000 specified in WPNS 114 in 1997 for the GBU-32 upgrade. Or it could be 4 x 250 lbs Small Smart Bombs with high penetration warheads. Prototype and production schedules for Tactical Tomahawk are not known but if an existing warhead is incorporated it seems likely that prototypes at least may have been among the 60 sea launched Tomahawks in the first week of the Afghan war. See also information on the Raytheon website at http://www.raytheon.com/es/esproducts/esprlist.htm#Missiles

AGM-84 SLAM-ER (Expanded Response) Block 1F, "a major upgrade to the SLAM missile that is currently in production, provides over twice the missile range, target penetration capability, and control range of SLAM. SLAM-ER has a greater range (150+ miles), a titanium warhead for increased penetration etc".. This reference to Titanium is inconsistent with all other reports about the physical properties required for penetrator warheads i.e. 2x the density of steel. It is probably a euphemism for a DU-Titanium alloy with < 1% Titanium. Warhead weight 488 lbs. " About 500 SLAM missiles will be converted to the SLAM-ER configuration between FY 1997 and FY 2001." See FAS http://www.fas.org/man/dod-101/sys/smart/agm-84.htm .

Storm Shadow / SCALP ER. This is a new European long range cruise missile project (joint BAE-RO and Matra) designed to use a BROACH warhead, strongly suspected of using a DU penetrator in its second stage. In Service Date was planned for late 2001. Similarities in function to the AGM-86D but possibly using the smaller BROACH warhead (500 lbs ?) developed for the AGM-154C in 1998-99. Production progress is not known but on original schedule it may have been used in Afghanistan for combat testing. http://www.fas.org/man/dod-101/sys/missile/row/casom.htm

Other cruise missiles suspected of using DU are those described as having "**heavyweight**" or **shaped charge warheads**, or both. Of these the most important is the **AGM-65G Maverick.** Commissioned in 1989 this radically pre-dates the new generation of advanced penetrator weapons. According to FAS "the **Maverick G** model essentially has the same guidance system as the D, with some software modifications that track larger targets. The G model's major difference is its **heavyweight penetrator warhead** [300 pounds / 135 kg, delayed-fuse penetrator], while Maverick A, B and D models employ the shaped-charge warhead."
See FAS at http://www.fas.org/man/dod-101/sys/smart/agm-65.htm



Picture © FAS

The AGM-65 Maverick has shaped charge or penetrator warheads depending on version.

Figure 1: Hard target guided weapons in 2001: smart bombs & cruise missiles with "dense metal" warheads

Warhead weight

SMART or GUIDED BOMBS	kg	lbs	CRUISE or GUIDED MISSILES
GBU 28 & GBU 37 Bunker Busters (BLU-113 Advanced Unitary Penetrator) >	2000	4400	
		4000	
	1500		
		3000	
	1000		
GBU-15, GBU-24, & GBU 27 GBU-31 JDAM > (BLU-116 or BLU-109/B penetrators)	900	2000	< **AGM-130C** (boosted GBU-15)
			AGM-86D CALCM (AUP3M 1200 lb)
		1200	↙ **AGM-158** **BGM-109**
	500		
GBU-32 JDAM > (AUP)		1000	< **JASSM** (AUP) **Tactical Tomahawk** (AUP)
		800	< **AGM-142** (I-800 AUP)
			↙ **Storm Shadow / SCALP-ER** (BR)
			↙ **AGM-154C JSOW** (BR)
	250	500	< **AGM-84 SLAM-ER**
		300	< **AGM-65G Maverick** (S/CH-P)
SSB Small Smart Bombs > (AUP or BR)		250	< **Hellfire; Brimstone** (S/CH)
	100		
A-10 strike 30mm x 200 rounds >	50	25	< **TOW 2 A/B** (S/CH or P)

Warhead weights include explosives (~20%) and casing. Dense metal ballast or liners (suspected to be DU) estimated to be 50-75% of warhead weight - necessary to double the density of previous versions. **AUP** = Advanced penetrators. **S/CH** = Shaped Charge. **BR** = BROACH Multiple Warhead System (S/CH+AUP). **P** = older 'heavy metal' penetrators.

The Maverick seems too lightweight to have been widely used in the Afghan conflict. Its prime importance in this DU investigation was its **widespread use in the Gulf War** (several thousand units) and its **international proliferation**. It has the highest US inventory level in the FAS smart weapons Index (40,000 units) and has been exported to many countries.

If one or more versions of the Mavericks in the Gulf War contained DU based warheads this could **significantly alter assessments of DU use in Iraq** - total tonnage, target locations, the geographic spread of DU contamination and hence exposure levels to civilians and veterans. It is reported that some of the UK veterans suffering Gulf War Syndrome had DU exposure ruled out because they had been involved in a Maverick friendly fire incident, not known DU anti-tank munitions. Veterans groups may wish to press for full investigation of all versions of the Maverick system for suspected DU use.

Hard target cruise missiles represent the second greatest DU threat in Afghanistan, and possibly the Balkans, after the guided bombs listed above. Their warheads are somewhat lighter because cruise missiles include fuel and propulsion systems, ranging from 300 - 2000 lbs. They are weapons of choice for hard or deep targets in heavily defended combat zones where aircraft may be at risk. They are also up to 3 times more expensive per size of warhead delivered than guided bombs so relatively less missiles than smart bombs may have been used in Afghanistan once air defences had been destroyed. However this conflict was ideally timed for **testing several newly produced or prototype missile systems** e.g. AGM-86D, Tactical Tomahawk, AGM-154C upgraded, SLAM-ER and Storm Shadow.

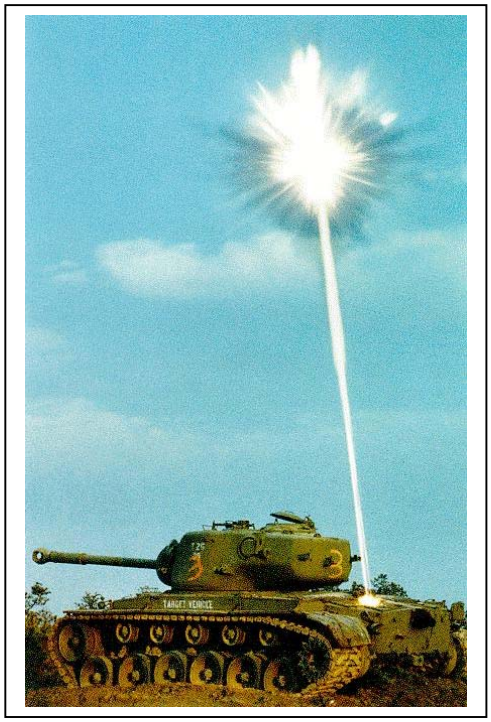
Suspected use of some of these systems in earlier conflicts in Iraq and the Balkans requires re-assessment of target zones and DU exposure in both regions.

7. Other suspected DU weapons systems

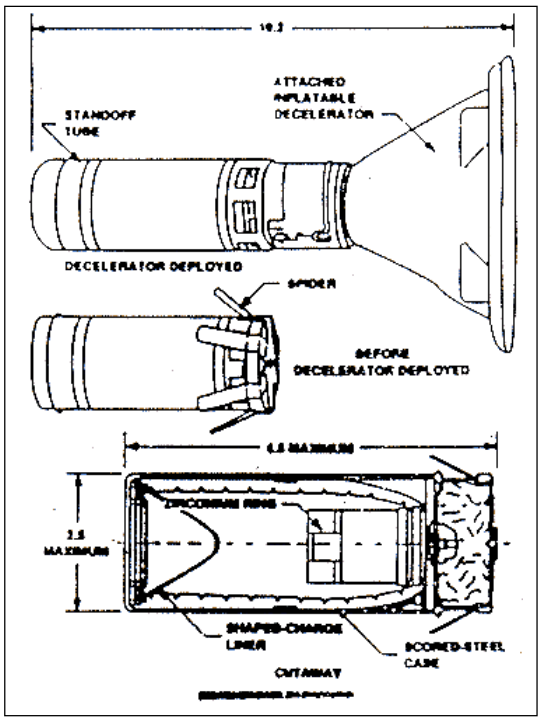
Other suspected applications of DU are in sub-munitions weapons.

Cluster bombs with anti-armour sub-munitions may use DU in their shaped charge liners. For example the CBU-97 contains 10 x **BLU-108/B** sub-munitions each with four armour-penetrating projectiles with infrared sensors to detect armoured targets…an ***explosively formed penetrator*** * fires at the heat source." see http://www.fas.org/man/dod-101/sys/dumb/cbu-97.htm and picture below left.

Pictures © FAS



BLU-108/B explosive formed penetrator



BLU-97B with shaped charge liner

The CBU-87 Combined Effects Munition contains 200 **BLU-97B** bomblets. This was the most widely used cluster bomb in the Balkans War. Its conical liner is shown in the diagram above (right) and in the full FAS description and illustrations at: http://www.fas.org/man/dod-101/sys/dumb/cbu-87.htm

The metal used for the shaped charge liners in both of these systems is not specified in FAS reports. But if DU is used it would add incendiary effects to each weapon. In both cases the combination of high temperatures and explosives would be likely to lead to 100% combustion if DU is used, with significant localised DU contamination hazards. **UNEP study teams in the Balkans were warned to stay clear of cluster bomb target zones for danger of unexploded munitions.** Ironically if either or both systems contain DU liners they may have yielded as much localised DU oxide contamination as the 30 mm penetrators they found. Since shaped charge liners project molten metal DU liners may burn up to 100% on impacting the target. This could be important in surveying suspected DU targets in Afghanistan i.e. to include DU inspections of vehicles or buildings damaged or burned by cluster bomb attacks. The possibility that wounds may also be DU contaminated is another consideration for medical teams treating cluster bomb victims.

* Note: A similar molten penetrator design is used in AT (anti-tank) Scatmines. See FAS at http://www.fas.org/man/dod-101/sys/land/m93.htm

Another type of sub-munitions suspected of containing DU warheads are the new range of smaller hard target weapons called **Small Smart Bombs (SSB's)** referred to as **"high density loadouts"** in the 1997 Concept Plan (see Tip of the iceberg in Part 1). According to the following FAS descriptions they achieve remarkable penetration for their size:

> "As of 07 January 1998 ACC approved a new acquisition strategy for the Small Bomb System (SBS) program. The Small Smart Bomb is a 250 pound weapon that has the same penetration capabilities as a 2000lb BLU-109, but with only 50 pounds of explosive. The submunition, with a smart fuze, has been extensively tested against multi-layered targets. The length to diameter ratio and nose shape are designed to optimize penetration for a 50lb charge.
>
> This weapon is also a potential payload for standoff carrier vehicles such as **Tomahawk, JSOW, JASSM**, Conventional ICBM, etc. The goal of the predecessor Miniaturized Munitions Technology Demonstration (MMTD) effort was to produce a 250-pound class munition effective against a majority of hardened targets previously vulnerable only to 2,000-pound class munitions. Using personnel and experience gained from the GBU-28 "Bunker Buster" program and the Exploitation of Differential Global Positioning System for Guidance Enhancement (EDGE) programs, the MMTD test team completed development testing in 18 months. McDonnell Douglas was awarded a $6 million contract to assist in the design and development of the MMTD concept. After completing successful warhead (Jan 96) and system (Mar 96) CDRs, the warhead already demonstrated the objective of penetrating 6 feet of reinforced concrete. "
>
> "The **second generation SSB** has an ***advanced warhead*** which is designed to maximize penetration capability without sacrificing blast/fragmentation potential. This is achieved by use of ***liners*** to control fragmentation and enhanced energetic explosives such as HMX or CL-20."

See http://www.fas.org/man/dod-101/sys/smart/mmc.htm and compare with the 1997 concept WPNS118 at http://fas.org/man/dod-101/usaf/docs/mast/annex_f/part26.htm

It is not known whether SSB's are already in use as Tomahawk or JSOW sub-munitions. The casing is described as "steel". But the above description fits the recurring theme of slim, ***high density*** warheads common to the advanced unitary penetrators from the same design team as the much bigger GBU-28.

A systematic investigation is needed of all the suspected DU weapons systems identified in Part 3 of this report, and of any other systems with similar warhead design features. This may be carried out by Parliaments in every country stocking these weapons seeking public disclosure by their military forces and by the weapons manufacturers concerned. Investigations may also need international co-ordination by the United Nations or International Court.

At the same time environmental review of all known training and combat target areas for these weapons is needed in case disclosure is not volunteered by the military. Any medical surveys of civilians and troops in regions within at least 10 kilometres of hard target bombs or missiles will also need re-assessment.