Overstating the case: an analysis of the utility of depleted uranium in kinetic energy penetrators
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Executive Summary

Introduction
In spite of longstanding concerns over their toxic and radioactive properties, depleted uranium (DU) weapons are retained by around 20 countries worldwide, primarily as kinetic energy weapons. Governments that use DU as a penetrator material often defend this choice by stating that its ability to penetrate armour is significantly greater than alternative materials.

ICBUW, and others, have questioned the legality of DU weapons, but in the past this debate has generally been restricted to the humanitarian and environmental effects of DU, rather than the military utility of DU weapons. This paper is intended to address the other side of the debate, to critically assess and to give some context to claims about the military utility of weapons containing DU.

While DU weapons do confer some military advantage, this advantage can also be gained through other means: DU does not therefore confer a unique military advantage. Thus, greater emphasis should be placed on humanitarian and environmental concerns when examining DU’s acceptability.

How effective is depleted uranium at piercing armour?
The reason that DU is considered to be so effective as a penetrator material is that it combines high strength and density with a type of deformation on impact known as ‘adiabatic shear’. While other penetrator materials (chiefly different alloys of tungsten) are of a comparable density to DU, they exhibit different deformation and fracture behaviours.

It is difficult to find information in the public domain about the effectiveness of DU and information that makes an exact comparison with other materials is even more difficult to access. However, internal UK government documents cite an improvement of about 15% in performance. A US government document suggests that DU offered an average of a 52% increase in penetration above that of the tungsten alloys.

These figures will not necessarily hold true for modern tungsten alloys, or indeed modern types of armour. Nevertheless, it seems reasonable to treat them as indicative and conclude that on a strict material-to-material comparison, DU is better at penetrating armour than presently available alternatives. However it seems likely that DU’s advantages as a material will be matched at some stage by new compounds. A 2009 review of alternative materials by staff from the US Army Research Laboratory identified nanocrystalline tungsten and bulk metallic glasses (BMG) as showing promise in key areas.

Other variables determining effectiveness of kinetic energy rounds
Penetrator material is only one among many variables which determine the effectiveness of a kinetic energy round. Although DU appears to be the most effective material, it is quite possible to achieve similar improvements in performance by other means.

Other significant variables that can be adjusted to increase the effectiveness of armour piercing rounds include the dimensions and shape of the penetrator. Reducing the weight or other performance-improving changes to the sabot can increase velocity, as can modifications to the barrel or improvements to the explosive charge.
It appears that modifications to the round, gun or other factors, which are unconnected to the choice of penetrator material, will often give more significant improvements to performance than changing penetrator material.

**Wider determinants of tank warfare effectiveness**

The anti-armour capability of tanks is dependent on numerous variables besides the basic engineering characteristics of the ammunition and gun. The accuracy of a shot, the speed at which it can be fired in response to sighting an enemy and the rate of fire can all play a critical role in tank-on-tank confrontations.

Few, if any, of the criteria which contribute to the anti-armour capability of tanks are so significant that any comparative disadvantages in that field cannot be offset by gains in another. Certainly this is not the case when selecting penetrator material.

**The best material for the job?**

**A historical case study of the development of the British CHARM rounds and Challenger 1 tank**

While a simple conception of ammunition development might state that the most effective material should always be chosen, in reality, procurement and development decisions are more complicated. This is well illustrated by the case study of the British Challenger 1 tank and the DU rounds developed for it.

Anti-armour tank ammunition is designed to defeat specific armour configurations. It is judged against its ability to defeat a range of armour fielded by potential enemies and on predictions of future enemy armour developments.

In the late 1970s, efforts to develop a common US, UK and German tank gun failed and the UK planned to develop a new tank on its own with a 120mm rifled gun. However, due to a combination of external circumstances, it was decided that the UK would purchase a derivative of the Chieftain tank, to be known as Challenger 1.

A DU round and a new high pressure gun were planned following projections of the type of armour expected in the successor to the Soviet T80 tank, but the gun would still be compatible with the Chieftain ammunition already in service. UK DU ammunition was developed because it was deemed necessary for defeating a particular type of armour and circumstances had limited the possibilities for adjusting other characteristics of the weapons system without a considerable investment of time and money.

**Consequences for present day UK tank ammunition**

Problems with the Challenger 1 tank necessitated an upgrade to the whole UK tank fleet. The updated tank, known as the Challenger 2, featured the high pressure gun, and a high pressure DU round, known as CHARM 3. This round finally became available in 1999 and remains the UK’s main anti-armour tank ammunition.

Rather than the brand new tank envisaged by military planners in the early 70s, the UK is fielding a tank with a gun that is the result of evolutionary adaptations from the Chieftain, where backwards compatibility has been a consideration at each stage. As a result, design of the CHARM 3 round is determined in part by decisions taken for a tank which first came into service in 1965. The limitations of this round and the lack of an export market have prevented any further development of UK armour piercing ammunition.

**Lessons from the CHARM case study**

Rather than starting with a blank slate and choosing the best material for the job, ammunition and procurement decisions are taken within a wider political and economic context, which may be considerably more important in determining round characteristics.

Since around 2002, UK planners have recognised that for reasons of cost and compatibility, future British
tank ammunition should be compatible with other NATO countries. However, a planned improvement involving non-DU ammunition, which has apparently proven to be more effective than CHARM 3 ammunition, has not been implemented for reasons of cost.

The UK’s switch to DU ammunition allowed them a ‘one-off’ increase in penetration, meaning that other procurement decisions could be taken for reasons of backwards compatibility and to support the British defence industry, rather than maximising effectiveness. However, in the long run, this has not prevented the round from becoming less effective than the non-DU system used by Germany.

**Conclusion**
The factors affecting ammunition design and penetrator material choice are far removed from a simple case of choosing the ammunition with the greatest possible military utility. Although straightforward engineering principles will inform the decision, wider considerations may be much more significant.

It is technically possible to design weapon systems that are equally as effective as DU using alternative materials. This is particularly true in the post Cold War era when the arms race between different armours and penetrators has largely ceased. All that is required is the political will for change within user states.

Although DU may, on consideration of penetrator material alone, be better at penetrating armour, this advantage is not so great that other adaptations cannot be substituted. When considered in light of the numerous disadvantages of using DU, ICBUW believes the perceived benefits well outweigh the costs.

There are some indications that this point of view is spreading from the many countries that have never sought to use DU weapons, to some of the states which were previously the most enthusiastic, with recent reports that the US is planning to develop a non-DU successor to its current 120mm DU round.

While DU may at present be the most effective penetrator material in a strict material-to-material comparison, this does not mean that DU ammunition is so militarily useful that alternatives cannot be found, given sufficient resources and political will. In light of the numerous problems regarding DU as a material, the case for user states to abandon these weapons is unanswerable.
Introduction
In spite of longstanding concerns over their toxic and radioactive properties, depleted uranium (DU) weapons are retained by around 20 countries worldwide, primarily as kinetic energy weapons using a long dart or penetrator for piercing armour. Governments that use DU as a penetrator material often defend this choice by stating that its ability to penetrate armour is significantly greater than alternative materials.

Under international humanitarian law, the impact of weapons on human health and the environment must be balanced against its military utility or effectiveness. If the weapon causes disproportionate harm to civilians or the environment it is not legal. DU has long been a suspected cause of health problems in the countries where it has been deployed. While there is still debate about the extent of the risk posed by these weapons, there can be no doubt about the widespread concerns about their effects, the environmental contamination that is left behind, and the difficulties this poses for countries emerging from conflict.¹

Because of these concerns, ICBUW and others have questioned the legality of DU weapons. However, this debate is generally restricted to the humanitarian and environmental effects of DU, rather than the military effectiveness of weapons containing DU. This paper is intended to address the other side of the debate, to critically assess and to give some context to claims about the military utility of weapons containing DU.

DU weapons are different from other types of weapons which have aroused significant humanitarian concern. Unlike anti-personnel landmines or cluster munitions, concern is focused on a particular material that is used as a component of kinetic energy weapons, and not on kinetic energy weapons per se. As such, DU weapons do not represent the sole route to achieving a distinct tactical effect, such as area denial or defeating dispersed targets – roles advocated for landmines and cluster munitions respectively. Instead, their perceived military advantage rests upon their claim to being more effective at performing a particular military role, compared to alternatives.

While DU weapons do confer some military advantage in that respect, and this paper identifies historical sources which quantify the extent of that advantage, it is clear that this advantage can also be gained through other means, such as improvements to the design of ammunition or armaments. As DU does not confer a unique military advantage, greater emphasis ought to be placed on humanitarian and environmental concerns when assessing its acceptability.

While ICBUW campaigns against the use of uranium in weapons, as an organisation we do not advocate the use of any weapons. While discussion of alternatives to using DU necessarily forms a significant part of this paper, it is not ICBUW's role to recommend alternative materials for the military and this paper should not be read as calling for their adoption.

While DU has occasionally been used in other roles,² in the main its use is as a penetrator material in large calibre armour piercing rounds fired by tanks – for use against other tanks and armoured vehicles. This is the role for which it has been suggested that DU is uniquely suitable. This paper

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² These include a Russian High Explosive Anti-Tank round, the 3BK-21B, and a Russian air-to-air missile, the R-60. Claims that DU is used in Tomahawk cruise missiles do not appear to have any basis in fact.
therefore focuses on this type of weapon. DU is also employed in some US medium calibre armour piercing munitions and instances of their use against non-armoured targets and civilian infrastructure have been documented. Given the longstanding concerns about DU weapons, DU’s use in these roles is even more questionable.

**How effective is depleted uranium at piercing armour?**

Historically, tank armour was comprised of plates of metal with the main differentiating factor being the thickness of the armour. While effectiveness against this type of ‘rolled homogeneous armour’ (RHA) is generally used as a benchmark for penetrators, most modern armour is made out of a classified combination of materials including metals, ceramics, empty space and explosive plates. These layers are arranged together in a way that tests have shown offers good protection against a variety of threats, of which kinetic energy penetrators are but one.

While most ammunition will have been designed to be effective against a range of different types of armour and protection, there may be considerable variation in effectiveness between these different types of armour. The eventual characteristics of the round are necessarily the result of engineering compromises and assumptions made about the type of armour it will be fired against.

The reason that DU is considered to be so effective as a penetrator material is that it combines high strength and density with a type of deformation on impact known as ‘adiabatic sheer’.3 Penetrators are designed to deliver the maximum energy to the area struck over the longest possible time. As such, penetrators are designed to be long and thin (the difference between penetrators in this respect is usually assessed by comparing the ratio of the length and diameter of the penetrator).

Penetrator materials are chosen to maximise strength and density. However the behaviour of the material under the extreme physical conditions of an impact also makes a difference. Adiabatic sheer means that material sloughs off from the point of the penetrator in such a way that it self-sharpenes, rather than becoming blunter as it passes through the armour. While other penetrator materials (chiefly different alloys of tungsten) are of a comparable density to DU, they exhibit different deformation and fracture behaviours.4

States are generally wary of releasing information into the public domain about the performance of their weapons. As such, it is difficult to find information in the public domain about the effectiveness of DU munitions versus rounds made with alternative materials. Information where only the penetrator material is altered and other round characteristics remain the same, so an exact comparison can be made, is even more difficult to access.

During internal UK government discussions on whether to begin developing DU ammunition it is stated that: “work that both we and the Americans have carried out so far show that depleted uranium penetrators give an improvement of about 15% in performance over the best tungsten

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3 DU is also pyrophoric, meaning that material from the penetrator ignites during impact. This burning material may ignite fuel or ammunition within the target vehicle, causing extra damage. However, in the documents examined for this study, DU’s pyrophoric nature is mentioned rarely, if at all. It would appear that for military planners, penetration of the target vehicle by a kinetic energy round is considered to likely have a disabling effect in any case. As such the extra damage caused by pyrophoric effects is of secondary importance if it is mentioned at all.

alloy penetrators”, presumably discussing penetration of rolled homogenous armour.5

A US government document from 1980 gives higher figures for a different, but related, metric – the ‘effective range’.6 These figures suggest that DU offered an average of a 52% increase in penetration above that of the tungsten alloys; though within this average the advantage ranges from 12% to 157%. It also appeared that the performance gap increased with the complexity of the armour in the target, and that tungsten rounds failed to penetrate the most advanced target.7

Of course, these figures will not necessarily hold true for modern tungsten alloys, or indeed modern types of armour, which are different from those used at the time of these tests. Nevertheless, it seems reasonable to treat these figures as indicative and conclude that on a strict material-to-material comparison DU is better at penetrating armour than presently available alternatives.

It is interesting that there does not appear to have been any change to the DU alloy used by the US since the 1970s, 99.25% DU mixed with 0.75% titanium.8 This alloy is also used by the UK and France, who manufacture their rounds from material provided by the US.9

Conversely, different alloys of tungsten have been developed over the years. It is perhaps significant that in the mid 1990s the penetrator materials strand of the UK’s programme for increasing the performance of the 120mm tank gun system concentrated on improved tungsten alloys, to the apparent exclusion of research on DU.10 This may have been because research on DU was continuing elsewhere, but it is more likely that DU was not thought to have potential for improvement as a material. The US government document comparing DU and tungsten penetrators says that tungsten “probably offers more areas for advancement or refinement in mechanical properties.”11

As such, it seems likely that DU’s advantages as a material will be matched at some stage by new compounds. A 2009 review of alternative materials by the US Army Research Laboratory identified nanocrystalline tungsten and bulk metallic glasses (BMG) as showing promise in key areas, including exhibiting adiabatic sheer, although a process for producing penetrators or similarly sized objects from these materials was said to be still some way off.12

Other variables determining the effectiveness of kinetic energy rounds
It is important to note, however, that this material-to-material comparison is far from being the

6 This would appear to refer to the furthest distance at which the round will still penetrate the target in question.
8 Earlier alloys, used in the Phalax Close In Weapons System and the Davey Crocket Spotting round were superseded by this alloy which was first developed for ammunition for the US A-10 gunship. See Peter K Johnson. ‘Tungsten Versus Depleted Uranium for Armour-Piercing Penetrators’. International Journal of Refractory Metals & Hard Materials (December 1983): 179–182 and Davit, op. cit.
10 See R J Mills. ‘Annual Assignment Report - Armoured Fighting Vehicles (Light And Heavy) - RO5A - 120mm Stretch Program’, April 26, 1995, Tank Museum Archive, Bovington. p65, where it is stated that the penetrator material component of the programme has a particular focus on tungsten alloys, but no mention is made of DU.
11 Davit, op. cit., p8
12 Dowding et. al, op. cit., p135-138
sole determinant of the military utility of DU weapons. Penetrator material is only one among many variables which determine the effectiveness of a kinetic energy round. Although DU appears to be the most effective material, it is quite possible to achieve similar improvements in performance by other means.

Other significant variables that can be adjusted to increase the effectiveness of armour piercing rounds include the dimensions and shape of the round - particularly increasing the ratio of the length to the diameter. Reducing the weight or other performance-improving changes to the sabot (the part of the round which allows the thin sub-calibre penetrator to sit within the larger barrel) can increase velocity, as can modifications to the barrel or improvements to the explosive charge.  

For example, the penetration ability of the US M829 round has been improved by increasing its length, and also by using lighter materials for the sabot. Similarly, ammunition for the German Leopard 2 tank has been improved by modifications to the penetrator, sabot and propellant, which have increased the penetrator weight but have also meant that the round leaves the barrel with increased kinetic energy. Later versions of the Leopard 2 are also fitted with a longer gun barrel. This means that the explosive force of the charge has longer to act on the penetrator as it travels up the barrel, increasing the velocity of the round.

This suggests that modifications to the round, gun or other factors, which are unconnected to the choice of penetrator material, will often give more significant improvements to performance than changing penetrator material. This is clearly shown in government documents from DU user states which, when discussing other changes to ammunition, state that these changes will give greater improvements in performance than the difference between DU and alternative materials.

For example, UK government papers dating from 1978 when the decision was made to develop a fin stabilised 120mm APFSDS round, instead of the then traditional APDS round, state that a DU APDS round would not be equal to the projected advances in Soviet armour, and therefore a tungsten APFSDS round should be developed instead.

Similarly, when discussing the possibility that political objections to DU weapons could prevent them being deployed to NATO forces in Europe, a 1980 US document predicts that the capabilities of the DU XM774 round could be exceeded by a tungsten version of the XM833 round, its successor.

**Wider determinants of tank warfare effectiveness**
The anti-armour capability of tanks is dependent on numerous variables besides the basic...
engineering characteristics of the ammunition and gun. The accuracy of a shot, the speed at which it can be fired in response to sighting an enemy and the rate of fire can all play a critical role in tank-on-tank confrontations.

Significant factors then, go beyond even technological improvements such as targeting systems and engines. They also include factors such as crew training, doctrine and ergonomics, all of which must be incorporated into decision-making at the design and procurement stage. As such, it is a mistake to fixate on one particular variable, in this case penetrator material, and over-emphasise its importance to the exclusion of all others.

While many of these metrics may be improved without compromising on the others; and it might be supposed that designers will strive to maximise performance on each conceivable criterion, in reality attention and research funding can only be diverted down a limited number of avenues.

Few, if any, of the criteria which contribute to the anti-armour capability of tanks are so significant that any comparative disadvantages in that field cannot be offset by gains in another. Certainly this is not the case when selecting penetrator material.

The best material for the job?

A historical case study of the development of the British CHARM rounds and Challenger 1 tank

While a simple conception of ammunition development might state that the most effective material should always be chosen, in reality, procurement and development decisions are more complicated. This is best illustrated using a case study of the British Challenger 1 tank and the DU rounds developed for it, and the context which informed these development choices.

Rather than aiming for an abstract maximum effectiveness, anti-armour tank ammunition is designed to defeat specific armour configurations. It is judged against its ability to defeat a range of armour fielded by potential enemies and on predictions of future enemy armour developments. At the time when the Challenger and its ammunition were being developed, this specifically meant Soviet tank armour.

In the 1970s, a trilateral agreement existed between the UK, US and West Germany to equip their tanks with a common gun, so that their separate tanks had interchangeable ammunition. During trilateral trials in 1975, the UK fielded a 110mm rifled gun with APDS ammunition. This was outperformed by two APFSDS rounds – a German round fired from a 120mm smoothbore gun and the new US DU XM774 round, fired from an older British gun barrel, the L7. Up to this time, the UK had been a leading nation in tank development and had been the origin of a number of

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20 These are much more numerous than the few key factors already discussed, and include barrel wear, gun alignment, barrel bend, barrel weight, barrel stiffness, expansion of the barrel, temperature and barrel wear (See ‘AFV Technology Aide Memoire’. Armour School - RAC Centre, March 1979. Tank Museum Archive, Bovington; H D Warwick. ‘A Third Supplement to MVEE Report 82019 - “A Guide To The Design of Main Armament Gun Mountings For Armoured Fighting Vehicles” (U)’. Procurement Executive - Ministry of Defence, 1987. Tank Museum Archive, Bovington.)


22 ‘Third supplement to the MVEE report’, op. cit. pD


24 The differences between APDS and APFSDS are outlined in footnote 5, above.

successful innovations, including APDS rounds, then the standard type of armour piercing ammunition.

At the time, there were still questions over the accuracy of APFSDS rounds but the decision to field an APDS round was probably also due in part to an institutional unwillingness to accept that this British invention had been supplanted. 26 Although the UK subsequently developed a prototype 120mm APFSDS round for subsequent trials, both the US and West Germany adopted a common system, the 120mm smoothbore L44 gun. 27 Meanwhile the UK planned to develop a new tank on its own with a different 120mm rifled gun. 28 This was partly justified as being necessary to retain compatibility with existing ammunition, including another British invention, the HESH round. 29

However, subsequent decisions were primarily the result of external circumstances. Firstly, projections for future improvements in Soviet armour were revised upwards, leading to the development of a tungsten APFSDS round (as mentioned above a DU APDS round was not deemed sufficient). 30 Then an ill-advised planned sale of tanks to the Shah of Iran did not go ahead due to his overthrow in the Islamic Revolution. The loss of this sale threatened the future of the Royal Ordnance factory in Leeds which had been due to produce them. 31 Thirdly, projections of the type of armour expected in the successor to the Soviet T80 tank indicated that the planned tungsten APFSDS round would not be able to fully penetrate it. 32

As the costs of the programme for the new tank were also increasing, it was decided that the UK would take up the shortfall from the failed Iranian sale. 33 The tank in question was actually a derivative of the Chieftain tank already fielded by the UK, but was to be known as Challenger 1. As the Challenger was equipped with the same 120mm rifled gun as the Chieftain, a new high pressure 34 gun would be designed, which could be retro-fitted to both the Challenger and Chieftain. A DU round would be developed for this gun (known as the L30), but it would be backwards compatible with the Chieftain ammunition then in service. 35

It is quite clear from internal documents from this time that development was specifically focused upon overcoming Soviet armour capabilities. 36 There were formal agreements between the NATO countries to devise accurate simulations of armour arrays for different types of Soviet vehicles to use for testing. 37 The detail in UK ammunition procurement documents shows that these criteria

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26 Orgorkiewicz ‘Armoured Fighting Vehicles’, op. cit., p125
27 Pengelley. ‘120mm Smoothbore Developers Vie for Leadership’, op. cit.
28 This was known as the MBT80, presumably a reference to 1980, then some time in the future. Prior to that, the UK had been planning to jointly develop a tank with West Germany, but that project appears to have soured during the time of the trilateral trials, presumably as a result of the failure to agree on a common barrel for the three nations. The tank the Germans then developed alone became the highly successful Leopard 2
29 High Explosive Squash Head (HESH). This type of round was not widely adopted by nations other than the UK, and was not designed with fins, and so required the rifled barrel to give it spin. However, as Orgorkiewicz (‘Armoured Fighting Vehicles’, op. cit., p125) points out, it would not have been difficult to add fins to the round
31 Orgorkiewicz ‘Armoured Fighting Vehicles’, op. cit., p137
32 See ‘GSR 3851 - 120mm Universal Depleted Uranium APFSDS Round’. Ministry of Defence, October 1, 1980. Tank Museum Archive, Bovington. Incidentally, the addition of a longer barrel to the German Leopard 2 tank was intended to counter the armour in an upgrade to the T-80: the T-80U, see Pengelley. ‘120mm Smoothbore Developers Vie for Leadership’, op. cit.
33 Orgorkiewicz ‘Armoured Fighting Vehicles’, op. cit., p137
34 i.e. able to withstand firings with a more powerful explosive charge and therefore to fire more powerful ammunition
35 ‘GSR 3851’, op. cit.

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were based on projected developments in Soviet armour.

During civil service discussions prior to the development program for a UK DU round, it is specifically stated in reference to the need for ammunition to counter Soviet armour that: “DU appears to offer the best prospects of such an improvement for the Chieftain’s main armament in a short timescale”. In other words, UK DU ammunition was developed because it was deemed necessary for defeating a particular type of armour and circumstances had limited the possibilities for adjusting other characteristics of the weapons system without a considerable investment of time and money.

Consequences for present day UK tank ammunition

The deployment of the new gun was delayed due to problems with the Challenger 1 tank, which necessitated a more fundamental upgrade to the whole UK tank fleet. The updated tank, which featured the new gun, was known as the Challenger 2 and entered service in 1993. DU ammunition compatible with the earlier gun was produced for the Challenger 1 just before the start of the Gulf War in 1991. A high pressure DU round, known as CHARM 3, finally became available in 1999, and remains the UK’s main anti-armour tank ammunition.

Rather than the brand new tank envisaged by military planners in the early 70s, in 2012 the UK is fielding a tank with a gun that is the result of evolutionary adaptations from the Chieftain, where backwards compatibility has been a consideration at each stage. As a result, design of the CHARM 3 round is determined in part by decisions taken for a tank which first came into service in 1965.

These include a rifled gun barrel, which makes UK ammunition incompatible with other NATO countries, and ammunition that is comprised of a separate charge and projectile. This means that there is no physical space in the round to accommodate a longer penetrator than that found in CHARM 3, meaning that the simplest ammunition redesign option is not a possibility.

As neither Challenger model has been successful on the export market, there has been little demand for the ammunition, resulting in the closure of the facilities used to manufacture CHARM 3. When combined with the diminishing importance of tank warfare in military priorities, these developments have prevented any further development of UK armour piercing ammunition. Meanwhile, the German L44 smoothbore gun, adopted by both the US and Germany after the 1975 trilateral trials has become the de-facto NATO standard, and is used worldwide.

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38 ‘DEFE 19/267 Depleted Uranium: Use in Conventional Armament - Research Firings’, n.d. UK National Archives. It should be noted that other considerations do play a role in these discussions, such as the implications for arm sales if other nations offer to sell DU ammunition and the UK does not, and the cost of the materials. However these clearly play a secondary role to the ‘requirement’ for ammunition that can penetrate a certain amount of armour (See also DEFE 11/919 New Weapon Technology, op. cit. and ‘DEFE 19/266 - Depleted Uranium: Use in Conventional Munitions - Research Firings’, n.d. UK National Archives)

39 In a similar vein, the first US DU round, the XM774, grew out of a 1973 project to improve the lethality of the existing M61 gun, so extending its life (See Office of the Special Assistant to the Secretary of Defense for Gulf War Illnesses. ‘1991 DU Use - Gulflink TAB E – Development of DU Munitions’, n.d.http://www.gulflink.osd.mil/ch_i/ch_i_table.htm.)

40 I.e. compatible with earlier versions. In this case guns have been designed to be compatible with older ammunition and ammunition has been designed to be compatible with older guns

41 Orgeriekiewicz ‘Armoured Fighting Vehicles’, op. cit., p125-126

42 This would likely not have been considered a problem in 1965, not least because APDS rounds have an upper limit to their length/diameter ratio. See D O S Whitley, ‘120mm Tank Guns’, Defence Sales, Tank Museum Archive, Bovington, pA-1

43 Only Oman has brought new Challenger 2 tanks. The UK’s Challenger 1 fleet was transferred to Jordan when the UK upgraded to Challenger 2

44 Pengelley. ‘120mm Smoothbore Developers Vie for Leadership’, op. cit.
Lessons from the CHARM case study
Although this example may well include particularly unfortunate procurement decisions and delays, there are characteristics which will be common to all ammunition design and procurement processes. Rather than starting with a blank slate and choosing the best material for the job, decisions are taken within a wider political and economic context, which may be considerably more important in determining round characteristics than pure engineering considerations.

The legacy of previous decisions and issues around compatibility stand out as being amongst the most significant factors, though it should be noted that decision-making on all these matters is coloured by group-think and institutional preferences. This is by no means restricted to British procurement. Another example would be the rejection of ‘Chobham’ composite armour by the US Military on the basis of early tests.46

Pursuing incremental developments of existing systems, rather than designing something entirely new, clearly conveys benefits in terms of cost, time required, and reliability. Presumably the preferred position for planners in terms of ammunition development is to have a selection of relatively low-cost changes which can be fairly quickly implemented in existing ammunition according to requirements. These changes can be implemented against a backdrop of longer-term, more investigative research into more fundamental changes.

The aim of this stance is to ensure that when incremental changes are no longer sufficient or practical, the costs and benefits of different development options are well understood, and the timescale and cost of developing prototypes into service can be estimated with sufficient accuracy. Towards the end of the Cold War, several significant step changes in tank gun systems were envisaged, with an understanding that a common 140mm NATO gun would be developed. This was then likely to be replaced with a gun using electromagnetic propulsion.47 In the event, neither of these developments has been deemed necessary, due to the end of the Cold War and the considerable slowing of Russian tank development.48 Instead, NATO tank ammunition development has restricted itself to improving 120mm ammunition.

Since around 2002, UK planners have recognised that for reasons of cost and compatibility, future British tank ammunition would have to be smoothbore ammunition of the type used by other NATO countries.49 To this end, the Challenger 2 tank has undergone testing with a German made smoothbore gun and non-DU ammunition, which has apparently proven to be more effective than CHARM 3 ammunition.50 However, due to reasons of cost, this upgrade has not been implemented.

45 Though it should be noted that this example is unusual in having two conflicting compatibility imperatives – compatibility with NATO allies, and backwards compatibility with the Chieftain tank
46 It is timely that the US saw an early prototype of this kind of armour, and dismissed its potential, possibly because early versions were less effective against kinetic energy rounds. It was subsequently adopted as the armour for the Abrams, but only due to the vociferous campaigning on the part of a few individuals against the settled institutional opinion. For a full description of this turn of events, see Kelly, Orr: King of the Killing Zone. New York: W.W. Norton, 1989
48 This is aptly illustrated by the 2010 cancellation of the Russian T-95 tank, which was to have been a revolutionary new design (see James M Warford. ‘The Soviet FST-2 and the Russian T-95: The New Russian Tank Generation Coming into Focus’. African Armed Forces Journal (September 2010): 18–21), but which became obsolete during two decades of development (see ‘Russian Tank Falls Victim to Intrigues - RusBizNews.com’, n.d. http://www.rusbiznews.com/news/n795.html). As a result, it could be argued that frontline Russian tanks have not undergone any major changes since the generation of vehicles that the UK’s original CHARM ammunition was designed for
49 The fact that this inevitable development was only internally admitted at such a late stage, following the decision by Greece not to adopt the Challenger 2 tank, illustrates the role institutional insouciance played in this case (see Rupert Pengelly. ‘Transition of Challenger 2 to Smoothbore Armament Reaches Significant Landmark’. International Defence Review (March 1, 2006))
50 This was first reported by the well-connected defence journal Jane’s International Defence Review, following trails in February 2006, Ibid. Although the results of the trials were officially classified, Jane’s was informed off the record that the test configuration outperformed a CHARM 3 round fired from the existing gun.
It is somewhat ironic that British government ministers often defend their current DU ammunition as being the best material for the job, having failed to bring in a more effective non-DU alternative.

The clear implication is that, while on a strict material-to-material comparison DU may be more effective at piercing armour than current alternatives, this effectiveness does not equate to an absolute military advantage. The same effectiveness can be achieved through other means.

The UK’s switch to DU ammunition allowed them a ‘one-off’ increase in penetration, meaning that other procurement decisions could be taken for reasons of backwards compatibility and to support the British defence industry, rather than maximising effectiveness. However, in the long run, this has not prevented the round from becoming less effective than the non-DU system used by Germany.

Conclusion
As the case study shows, the factors affecting ammunition design, and penetrator material choice, are far removed from a simple case of choosing the ammunition with the greatest possible military utility. Although straightforward engineering principles will inform the decision, wider considerations may be much more significant.

It is technically possible to design weapon systems that are equally as effective as DU using alternative materials. This is particularly true in the post Cold War era when the arms race between different armours and penetrators has largely ceased, or at least considerably slowed down. All that is required is the political will for change within user states to discontinue using DU and, if they wish to develop their own bespoke range of ammunition systems, to spend the necessary sums on development.

Although DU may, on consideration of penetrator material alone, be better at penetrating armour, this advantage is not so great that other adaptations cannot be substituted. Furthermore, when considered in light of the numerous disadvantages of using DU – the potential health and psychological impact on civilians and military personnel, the environmental contamination, handling issues, the cost of decontamination (i.e. cleaning up domestic ranges and production facilities), potential liabilities for decontamination overseas and the political unacceptability in many quarters, ICBUW believes the costs well outweigh the perceived benefits.

There are some indications that this point of view is spreading from the many countries that have never sought to use DU weapons, to some of the states which were previously the most enthusiastic. The United States has taken a long term decision to discontinue using DU in medium calibre rounds. Strikingly, when tendering the contract for the ammunition for the F-35 Joint Strike Fighter, the US listed the presence of “toxic materials such as Cobalt, Nickel, Beryllium or depleted-Uranium” as being non-desirable criteria for potential bidders. They later purchased a tungsten-based round from the German manufacturer Rheinmetall, as they were the only supplier to satisfy all the requirements. Although they currently retain the A-10 gunship in service, which fires a 30mm DU round, during 2011’s Operation Unified Protector in Libya it appears that a decision was taken not to use the DU ammunition, presumably because of its political unacceptability.

52 US denies depleted uranium use in Libya, but refuses to rule out future use: http://www.bandepleteduranium.org/en/a/402.html

ICBUW – Overstating the Case: an analysis of the utility of depleted uranium in kinetic energy penetrators www.bandepleteduranium.org
Recent reports suggesting that the US is also planning to develop a non-DU successor to its current 120mm DU round appear to confirm this picture. While DU may at present be the most effective penetrator material in a strict material-to-material comparison, this does not mean that DU ammunition is so militarily useful that alternatives cannot be found, given sufficient resources and political will. Given the numerous problems regarding DU as a material, the case for user states to abandon these weapons is unanswerable.

53 ‘NATO Tanks Aim at Wider Target Set with Smoothbore Ammunition’. International Defence Review (January 19, 2012)