如何應用砲管磨損初速變量使砲口初速更精準

The utility of MVVWEAR in enhanced muzzle velocities

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In “Enhancing Muzzle Velocity Management,” Army and Marine captains from the Fort Sill Gunnery Department identified current knowledge gaps across the field artillery in regards to the enhanced muzzle velocity mode used by the Advanced Field Artillery Tactical Data System（AFATDS）and Digital Fire Control Systems（DFCS）. Most of the confusion concerning the new system revolves around the MVV_{WEAR} term, which is often conflated with tube wear or simply not understood at all. This article will elaborate further by first defining the type of muzzle velocity data that MVV_{WEAR} represents, then demonstrating how this data is determined and applied, and finally by assessing its current and future utility in meeting the third requirement for accurate predicted fire: accurate weapons and ammunition information.

在〈加強版砲口初速管理〉[1]一文中，美砲校射擊組學官們點出當前砲兵部隊使用「先進野戰砲兵戰術資料系統」（AFATDS）及「數位化火力管制系統」（DFCS）[2]對如何加強砲口初速管理在認知上的不足。對新裝備的理解大多數圍繞 MVV_{WEAR}（譯註 1：因磨損造成之初速變化量）這一術語，經常將此一術語與砲管磨損混為一談，或壓根不進入狀況。本文首先進一步說明 MVV_{WEAR} 所代表的初速數據類型，然後說明如何確定並應用該數據，最後通過評估說明現在與未來如何運用，方能滿足精準預測火力（譯註 2：即不經試射效力射）的第三項要求：精準的武器與彈藥資訊（譯註 3：精準的不經試射效力射有五項要求：精確之 1.目標位置、2.陣地位置、3.武器及彈藥資訊、4.氣象、5.計算過程）。

A measured Muzzle Velocity Variation （MVV） developed through firing contains all 14 factors that affect muzzle velocity. Traditionally, only propellant efficiency （PE/MVV_{LOT}） and tube wear （measured as a shooting strength or in equivalent full charges （EFCs） were included in the predictive calculation for an MVV. The other factors were either averaged out by firing six usable rounds, or ignored because they are

[1] 請參閱 Wish, Guglielmo, Williams, Kilgore, Muma, Dunham, and Leija 合撰之〈加強版砲口初速管理（Enhancing Muzzle Velocity Management）〉，刊登於 Fires, 2018, pp 52-59.

[2] 為求簡便，本文統一採 DFCS 代表 PDFCS（Paladin） 及 DFC（M109A3），因後兩者均備相同之加強版砲口初速功能。

preventable through good training and supervision, or were simply too difficult to measure. Assuming the unit follows proper procedures and accurately accounts for tube wear through pullover gauge （POG） measurements and predicting EFCs, the remaining factors are captured in the MVV_{LOT} （PE） measurement.

射擊後產生的砲口初速變化量（MVV）包含了影響初速的所有 14 項因素（譯註 4：1.初速趨勢、2.砲彈批號、3.裝備之公差、4.砲管磨損、5.不正常之送彈動作、6.旋轉帶、7.藥溫及彈溫、8.發射藥溫度、9.藥包在藥室之位置、10.裝藥重量、11.殘留銅屑、12.發射藥殘渣、13.砲管狀況、14.其他，如砲管記憶與跳動，引自《FM6-40 射擊指揮 1996.4.23 版》）。 傳統上，MVV 的預測計算只考量發射藥效率（PE / MVV 批號）和砲管磨損〔量測射擊強度（譯註 5：影響射擊強度 shooting strength 因素有 1. 砲管磨損、2.製造公差、3.後座力之影響）或「等同全裝藥」（EFCs）〕。其他因素則以射擊六發有效射彈求其平均值，[3]或根本予以忽略，因為它們可以經由良好的訓練和監督來預防，或者只是量測不易。[4]假設部隊能正確使用「拉膛規」（pullover gauge, POG）測量並預測 EFC，計算出砲管磨損，則其餘因素都包含在 MVV 批號（PE）數據內。

The enhanced muzzle velocity system attempts to isolate and quantify some of these factors from the MVVLOT value yielding a new term called MVVWEAR. MVVWEAR is the effect, measured as a change in muzzle velocity, of machining tolerances in chamber and tube construction.

加強版砲口初速系統試圖從 MVV 批號值中分離出若干影響因素，並加以量化，因而產生 MVV 磨損此一新名詞。MVV 磨損其實是藥室與砲管結構公差的影響下，量測出來的初速變化。

“In a new tube, the size of the powder change and the interior dimensions of the bore” can cause non-standard muzzle velocities wherein “a variation of 4 meters per second between the cannon developing the greatest muzzle velocity and the cannon developing the lowest muzzle velocity would not be unusual.” [5]

「新的砲管中，發射藥量與砲膛空間誤差」都會造成非標準的砲口初速，「最大變化達每秒 4 公尺並不罕見。」[5]

The differences in tube and/or chamber construction is represented by the MVV_{WEAR} term and can be determined with the enhanced system.

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[3] Less than six rounds could be used, with decreasing assurances of validity, MCRP 3-10E.4 Chapter 10, p10-6 （TC 3-09.81 Chapter 10, p10-4）.

[4] A third case includes those that are measureable, but the increased accuracy is negligible and therefore does not justify the measurement. Projectile temperature is an applicable example.

[5] MCRP 3-10E.4 Chapter 3, p 3-8 （TC 3-09.81 Chapter 3, pp 7-8）

砲管及藥室結構的誤差以 MVV 磨損術語表示，可顯示在加強型砲口初速系統。

Calculating MVV_{WEAR}

$$MVV(Measured) = MVV_{EFC}(Measured) + MVV_{LOT}(Unknown) + MVV_{WEAR}(Unknown)$$

The fundamental problem in determining MVV_{WEAR} is that the equation yields two unknown variables with no easy method of isolating one in order to determine the other. In order to isolate the two variables, MVVs must be measured across multiple propellant lots and a relative comparison can be made by assuming that the average PE of a sufficiently large sample of lots is zero. In other words, if a howitzer fires a large number of lots and the all of the PEs it measures average to a large positive number, it is more likely that this howitzer simply fires faster than the standard howitzer.

MVV 磨損之計算

$$MVV（量測） = MVV\ 等同全裝藥（量測）+ MVV\ 批號（未知）+ MVV\ 磨損（未知）$$

確定 MVV 磨損的根本問題是等式內有兩項未知變數，很難隔離任一項來確定另一項。除非經由多個發射藥批號量測 MVV，同時多批號彈藥射擊樣本數量要夠大，假定其平均 PE 為零來做相對性比較。換言之，若火砲射擊批號數量多，所有 PE 平均值為一個大的正數，那麼火砲初速值就較標準為大。

An example best illustrates the principle. Suppose a brand new howitzer arrives at a unit. Given it has not yet fired its first round, its shooting strength is zero.6 In this case the howitzer’ s powder chamber was constructed slightly smaller than the standard howitzer and it therefore fires 1.0 m/s faster than the standard muzzle velocity. If this howitzer then fires several rounds from six different lots of propellant, whose PEs average to zero, then the data might appear, see table below.

茲舉一個例子說明其中道理。假設部隊剛接收一門從未射擊過的全新的火砲，其射擊強度為零。[6]火砲的藥室較標準略小，因此比標準初速快 1.0 公尺/秒。若該門火砲以六個不同批次射擊數發砲彈，其 PE 均值為零，則數據如下表。

Note that the average PE is zero. However, because the DFCS does not yet know what its MVVWEAR value is, it assumes MVVWEAR is zero, so to the DFCS the data will actually appear as in the table below.

請注意，平均 PE 為零。但是由於 DFCS 還不知道它的 MVVWEAR 值為何，故假定為零，因此 DFCS 實際顯示數據如下表。

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[6] 該範例假設射擊全程射擊強度均為零，此現象在射擊小號裝藥時，其等同全裝藥對砲口初速影響甚微（如 1L 裝藥等同 0.01 等效全裝藥，不論射擊何種彈藥家族，其砲口初速變化均小於 1/1000 公尺每秒）。

Because the PEs average to +1.0 m/s and the DFCS assumes they should average to zero, it strips out the +1.0 and stores it as MVV_{WEAR}, rightly assuming that the one meter per second bias is due to the howitzer firing faster than the standard. This method only works if the howitzer fires a sufficient number of different lots in order to achieve an appropriate sample size. Six lots is suitable per the assurance of validity table.7

由於 PE 的平均值為+1.0 m / s，而 DFCS 假定其為零，它會分離+1.0 並將其存儲為 MVV 磨損，正確地假設每秒一公尺的偏差是由於火砲的射擊速度快於標準值。只有當火砲射擊樣本的批號足夠，此方法才有效。宜以六個批號射擊，確認驗證表有效。[7]

Shooting Strength	MVV_{WEAR} R	MVV_{LOT} (PE)	MVV
0.0	1.0	-2.3	-1.3
0.0	1.0	1.2	2.2
0.0	1.0	1.5	2.5
0.0	1.0	-0.3	0.7
0.0	1.0	-3.9	-2.9
0.0	1.0	3.6	4.6
	Average:	**0.0**	**1.0**

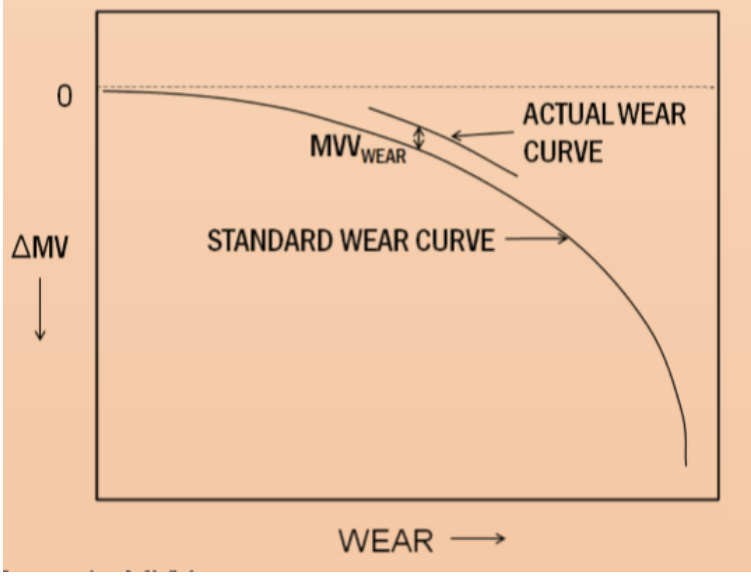
Shooting Strength	MVV_{WEAR} R	MVV_{LOT} (PE)
0.0	0.0	-1.3
0.0	0.0	2.2
0.0	0.0	2.5
0.0	0.0	0.7
0.0	0.0	-2.9
0.0	0.0	4.6
	Average	**1.0**

The term MVV_{WEAR} derives from how this initial bias affects the wear curve of a howitzer. Tube wear still causes a loss in muzzle velocity in all cannon tubes8 in approximately the same way, depicted below by the "standard wear curve." In essence, a variation in a tubes initial conditions （tolerances in new weapon systems） shifts this curve up or down by a specific amount （MVV_{WEAR}）, producing the "actual wear

[7] MCRP 3-10E.4 Chapter 10, p10-6 （TC 3-09.81 Chapter 10, p10-4）同樣邏輯適用於以六發射彈平均值的傳統原級校正。

curve." The figure below represents a positive MVV_{WEAR} value.9

MVV 磨損一詞源於初始偏差對火砲磨損曲線的影響。砲管磨損同時對所有火砲的初速都會與「標準磨損曲線」有差異，如下圖所示。[8]實質上，砲管初始條件的變化（新武器系統的公差）使這條曲線上移，或者按特定量（MVV 磨損）下降，產生「實際磨損曲線」。下圖表示 MVV_{WEAR} 之正值。[9]



Errors in MVV_{WEAR}

The underlying assumption that allows the system to capture the magnitude of tolerances in new weapon systems is that the average variation of PEs across many lots is zero. This assumption may not be warranted given the incorrect muzzle velocity of the Charge 1L （propellant model M231）, degradation of propellant lots over time, and reported inconsistencies with Charge 1L when firing the M795 family of projectiles.

MVV 磨損之誤差

允許系統掌握新武器系統中公差大小的基本假設是，各批號彈藥的 PE 的平均變化量為零。當 1L 號裝藥（M231 發射藥）的初速不正確，發射藥批號隨時間的退化，加上在以 1L 號裝藥射擊 M795 系列砲彈時，回報的不一致，可能此一假設就無法成立。

The standard muzzle velocity for M231 Charge 1L is incorrect in the Tabular Firing Tables by approximately -2.0 m/s. This is reflected in the procedures for predicting an

[8] 鉻金屬內殼砲管磨損甚少，其磨損曲線終其壽期損失低於 2 公尺每秒。目前極少單位裝備該式砲管。

[9] Note: MVV_{WEAR} can change over time: the DFCS will compare future MVVLOT values determined during firing and can update the original determination. However, the DFCS will have to fire a large quantity of new propellant lots and the updated value will have to significantly differ from the original estimate. The procedure used has a low likelihood of changing the original MVVWEAR value.

MVV for 2L, which requires that "from 1L data" one must "apply a +2 m/s correction." Averaging the most recent Modular Artillery Charge System PE tables confirms this bias and actually produces an average Charge 1L PE of -2.4 m/s.10 Due to the error in standard muzzle velocity, any unit predominantly firing Charge 1L during its first six lots will likely produce an MVV_{WEAR} value that is negatively biased. Because of the incorrect MVV_{WEAR} value, all future MVV_{LOT} measurements determined by the DFCS will be affected. This effect is likely to occur for units that tend to fire on smaller installations with limited opportunities to fire higher charges.

M231 1L 號裝藥的標準初速與射表所載，大約相差-2.0 m / s。當「以 1L 裝藥數據」預測 2L 號裝藥的 MVV 時，須作+2 m / s 修正。從最近的「砲兵模組化裝藥系統」（Modular Artillery Charge System）PE 表平均值看，確認了這種誤差，1L 號裝藥 PE 的實際平均值為-2.4 m / s。[10]由於標準初速的誤差，任何在前 6 次批號 1L 號裝藥實施射擊 MVV_{WEAR} 可能是負值。由於 MVV 磨損值不正確，DFCS 確定的 MVV 批號都將受到影響。對於那些傾向於在小型裝置實施射擊，且射擊較大裝藥機會較少的單位而言，可能會發生此一效應。

While more empirical data is needed, the general experience of most fire direction center Marines and Soldiers is that PEs tend to be more negative than the published list. While the causes may not be definitely known, it seems unlikely that propellant will somehow gain efficiency over time. Rather it is much more likely that humidity, temperature, storage procedures and handling procedures combine to degrade PEs, especially over prolonged periods. Some older lots of M231 propellant have produced astonishingly negative PEs, some as extreme as -25 m/s.11 Should any of these older lots be present during the firing of a howitzer's first six lots, the MVV_{WEAR} value would be heavily biased and very likely inaccurate.

雖然需要更多的實證數據，但大多數陸戰隊射擊指揮所的總體經驗是，PE 往往比公佈的數據負得更多。雖然原因可能並不清楚，但發射藥似乎不太可能隨時間更有效率。反而可能因濕度、溫度、儲存程序和處理程序等因素結合後降低了 PE，特別是經過長時間儲存後。一些較老的 M231 發射藥出現驚人的負值 PE，甚至達到-25 m / s。[11]如果火砲的前六批號屬於老舊批號，MVV 磨損值將嚴重偏移，且極可能不準確。

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[10] 請參閱 2016 年 7 月 7 日 6-02 版 155mm 模組化裝藥射表發射藥效能（Propellant Efficiencies，PE）欄。

[11] 作者擔任副連長期間實施原級校正射擊時，使用的 M231 發射藥曾儲存在中東地區，儲存時間不詳，量測出之 PE 約為-25 m/s。

Finally, another general report from field artillery units is large variability in firing the M795 projectile family with Charge 1L and 2L.12 Recently India Battery, 3rd Battalion, 11th Marines reported a discrepancy in MVV_{LOT} data while firing coordinated illumination missions. The fire direction officer （FDO） discovered that all four of their howitzers determined an average MVV_{LOT} of -6.4 m/s when firing the M485A2 illumination projectile, which is in the M107 projectile family. Yet, those same four howitzers determined an average MVV_{LOT} of -12.3 m/s when firing M795.13 More empirical data is needed in this case as well, but it is not uncommon for units firing M795 with M231 propellant to report measured MVV_{LOT} values in the negative double digits, far below that of the published tables and significantly different from the same lot when firing other projectile families.

最後，砲兵部隊的另一份一般性報告稱，以 1L 及 2L 裝藥射擊 M795 系列砲彈發現變化極大。[12]最近第 11 陸戰團，第 3 營，I 連回報，實施協調照明任務時 MVV 批號數據的差異。射擊組長（FDO）發現他們的四門榴砲在射擊 M487A2 照明彈時平均 MVV 批號為-6.4 米/秒，這也是屬於 M107 砲彈系列。然而，同樣的四門砲射擊 M795 砲彈時，平均 MVV 批號則為-12.3 米/秒。[13]這種情況也需要更多的實證數據，但在部隊報告中使用 M231 發射藥射擊 M795 砲彈測量出兩位數負值 MVV 批號並不罕見，遠低於射表的數值，同時與相同批號射擊不同系列砲彈時有極大差異。

The utility of MVV_{WEAR}

Even if one assumes a reasonable accuracy in measuring MVVWEAR values, the utility of capturing this value still remains in question. In reality, the principle benefit of determining MVVWEAR is not to allow a unit to fire more accurately, but rather to determine more accurate PEs. When conducting calibrations in basic mode, MVV_{WEAR} was never individually accounted for, yet units managed to accurately meet the third requirement for accurate predicted fire. All of the muzzle velocity data was simply captured in one term （MVV）. The enhanced system even further reduces the need for MVV_{WEAR}, as it begins calibrating with the first rounds fired and continues to calibrate with each subsequent round. Without an MVV_{WEAR}, all remaining muzzle velocity data is simply captured in MVV_{LOT}. It does not matter to the firing unit where the data is captured, as long as it is captured and applied the howitzer will fire accurately.

MVV 磨損之應用

[12] 該兩裝藥通常出現負值，而 1L 裝藥變化更大且不穩定。

[13] 該連以 M231，2L 裝藥，批號為 GDB04H-072295 發射藥射擊時，射表 PE 欄為-2.0 公尺/秒

即便假定測量 MVV 磨損數值具有相當合理的準度，但如何加以運用仍是問題。實際上，確定 MVV 磨損的主要好處並不在使射擊更準確，而只是確定 PE 更準確。在原級校正時，MVV 磨損從未被單獨考慮過，而在設法滿足準確預測火力的第三項要求。 所有砲口初速數據都包含在一個術語（MVV）。加強版系統甚至進一步降低對 MVV 磨損的依賴，因為在第一波射擊時就開始校正，爾後更持續校正。不考慮 MVV 磨損，所有初速數據都包含在 MVV 批號中。對射擊單位而言，數據從何而來並不重要，只要能精準射擊就可以了。

If the capturing the total MVV allowed units to fire accurately, then the utility of determining MVV_{WEAR} appears to be diminished, but stripping out this value is still useful in that it produces a more accurate PE. However, if this PE is not useful in some capacity, then its accurate determination is not necessary. The only use for this PE is to provide the most recent propellant lot data to other units, who may choose to predict muzzle velocities for a more accurate first round until the unit begins firing rounds and determines its own PE data. The problem with this practice is that it is not often used for two reasons: Most battalions and regiments do not currently track PEs14 and when they are shared many units do not trust the values, preferring instead to simply fire and measure their own data. To borrow from the field of economics, the marginal benefit of producing and applying slightly more accurate PEs for only one round fired （the first round on a new lot） does not appear to justify the relatively large cost of managing and tracking the measured data on a large scale. This is especially true when units already have access to PE data from the established tables.

如果 MVV 總值可以讓部隊精準射擊，則準確的 MVV 磨損的用處就不大了，但是該數值仍然是有用，因為由它可以獲得更準確的 PE。但是，如果此 PE 在某些狀況下也不需要，那麼也就不必加以計較。PE 的唯一用途是向其他單位通報某批號發射藥的最新數據，接收的單位可以據以預測砲口初速，以獲得更準確的第一發效果，直到該單位從後續射擊中獲得自己的 PE 數據。這種做法的問題在於它通常不會被使用，原因有二：目前大多數營與團都沒有追踪 PE 的習慣[14]，許多單位即便收到通報也不會信任這些數據，寧願直接進行射擊自己量測。從經濟學觀點看，只為了一發射彈（新批號的第一發）稍微精準的 PE 所產生的邊際效益，似乎不足以證明大量數據的追蹤與管理是有價值的。當部隊可以從現行射表中查取若干 PE 資料時尤其如此。

In the case where a unit does use a PE determined from another firing unit （or the

[14] The 10th and 11th Marine Regiments have recently updated their muzzle velocity management policies in an effort to track PE data.

published PE tables）, the unit cannot transmit the predicted data to the DFCS before it has fired its first six lots. Any forced MVV_{LOT} from AFATDS to the DFCS will reset the counter on the DFCS for the six lots it needs to determine MVV_{WEAR}. The irony is that if a few units develop largely accurate PEs for many lots, other units who have not yet fired six lots will simply force the PEs to the DFCS in an effort to be as accurate as possible on the very first round and delay their own ability to determine MVV_{WEAR}.

當部隊不採用其他單位的 PE（或射表的 PE 欄），就無法在射擊頭六個批號射彈前傳輸預測數據給 DFCS。若從 AFATDS 強迫將 MVV 批號傳輸至 DFCS，將使 DFCS 上為了確定 MVV 磨損所需的六個批號的計數器重置。諷刺的是，如果少數單位為求取準確的 PE 實施多批號射擊，其他尚未射擊六個批號的單位僅僅將通報 PE 強制輸入 DFCS，以期盡可能達到第一發奏效的射擊，並延遲本身求取 MVV 磨損的能力。

Consider that the validity of the MVV_{WEAR} measurement entirely rests on the assumption that six randomly fired lots will produce PEs that average to zero; this assumption rests on the fact that the published PE tables average to zero. If howitzers with MVV_{WEAR} values determined in this way later on measure any PE that departs significantly from the PE tables, then its MVV_{WEAR} value accuracy is automatically suspect, because it conclusively demonstrates that the tables do not actually average to zero. In other words, if The battery was firing M231, Lot GDB04H-072295, Charge 2L. The PE table value for the charge and lot is -2.0. The 10th and 11th Marine Regiments have recently updated their muzzle velocity management policies in an effort to track PE data. the current tables are accurate and stable over time, then there is no need to measure Pes. If they are not accurate, then MVV_{WEAR} values are being determined incorrectly and the PEs being determined are not accurate. Finally, if the PE tables truly are accurate, then why aren’t they simply stored in the DFCS as permanent MVV_{LOT} data? If there is an institutional acceptance that the values in the table are subject to change, then the initial premise for the validity of the MVV_{WEAR} calculation is at best questionable.

考慮到MVV 磨損測量的有效性完全取決於六個隨機挑選批號射擊後PE平均為零的假設，而此一假設又是根據射表 PE 欄平均為零的事實。若火砲 MVV 磨損依據測此一方式量測，據以推算的 PE 與設表所載差異極大，則 MVV 磨損值得準確度必受懷疑，因為射表上顯示平均值並不為零。換句話說，假定射擊 M231 發射藥，批號為 GDB04H-072295，2L 號裝藥，射表 PE 欄顯示為-2.0。陸戰隊第 10 和第 11 團最近更新了其初速管理政策，以追踪 PE 數據。發現表列數據一直相當準確和穩定，因此無需量測 PE。如果不準確，則 MVV 磨損值及 PE 值亦不

準確。最後，如果表列 PE 值確實準確，那麼為什麼不將 MVV 批號數據永久存儲在 DFCS 中？如果大家都認為表列數值會變化，那麼 MVV 磨損計算的初始前提就值得懷疑了。

The determination and application of MVV_{WEAR} has unnecessarily caused a large amount of confusion in the fire direction community. The calculation of the value is entirely tied to an assumption that, pending further empirical data, may prove to be unreliable. In real world terms, there is little value added to the unit, which only cares that muzzle velocity data is captured and saved by lot. It matters very little if the MVV_{LOT} value is truly the PE, or also contains captured data from the other factors that affect muzzle velocity. In terms of data collection, the process of updating PE data provides little utility when units are willing to accept a small amount of inaccuracy on the very first round fired, especially given a system that will immediately begin calibrating with each round fired. This risk may be larger if units are experiencing severely negative PEs, but if this is the case it only buttresses the case against the calculation assumptions for MVV_{WEAR}.

MVV 磨損的確定和應用不必要地引起了火力社群的大量混亂。該數據的計算完全基於於一個假設，即等待進一步的實證數據，可能證明是不可靠的。在現實世界中，部隊需求上並沒有那麼大，他們關心的，以及儲存的只是砲口初速。對 MVV 批號值是否即實際的 PE，或是否包含影響初速的其他因素，其實並非重要。在數據收集方面，當部隊願意接受第一波射擊少量的不準確程度，更新 PE 數據的過程幾乎沒有用處，特別是考慮到每一波射擊都會立即時修正的狀況。如果部隊遭遇嚴重的負值 PE，風險可能會更大，如果出現這種情況，就會支持 MVV 磨損的計算假設。

No matter the utility of MVV_{WEAR}, it is vitally important that units use the current system as designed in order to gather data for further analysis. No conclusive case can be made if units do not fire digitally with the enhanced muzzle velocity system. Artillery headquarters units should establish muzzle velocity management policies that track all MVV_{WEAR} and MVV_{LOT} data within the unit and all accumulated data should be submitted to the Fires Center of Excellence aboard Fort Sill, Okla.

無論 MVV 磨損的實用性如何，部隊以現行系統蒐集數據進行進一步分析至關重要。若射擊時不使用加強版初速系統，則無法該射擊結果無法應用。 砲兵指揮部應建立初速管理政策，跟踪各單位所有 MVV 磨損和 MVV 批號數據，所有累積的數據應提交給位於奧克拉荷馬州西爾堡（Fort Sill）的火力卓越中心（Fires Center of Excellence）。

The way forward

In order to better account for the third requirement, the community needs to update the Charge 1L standard muzzle velocity, develop and consolidate as much firing data as possible in order to determine the validity of the PE tables over time, and assess any potential problems with the M795 projectile family. Simple tests can be conducted by training and force units to accomplish this collection. However, it is incumbent upon unit leaders to ensure data collection occurs under as ideal conditions （meeting the five requirements） as possible. With the right data, it is entirely possible that the issues presented here are unfounded or affect the determination of MVV_{WEAR} by a sufficiently small magnitude that the procedures for its computation still remain valid. Assuming these issues are validated, then the assumption concerning average propellant lots may no longer hold true.

未來展望

為了更好地考慮第三個要求，砲兵社群必須隨時更新 Charge 1L 標準初速，盡可能累積射擊數據，不對確定 PE 表的有效性，同時評估 M795 系列彈頭任何潛在的問題。透過訓練與強制力，要求部隊實施此數計之蒐集。主官有責任確保相對理想的條件下（滿足五項要求）進行數據收集。即便程序、計算正確，數據也正確，亦極可能無法解決上述問題，或小幅度影像 MVV 磨損。假定上述問題存在，則發射藥批號平均值就不一定永遠正確。

If this is the case, two options remain: disregard MVV_{WEAR} and allow those values to be trapped in the measured PEs, or find a new method for determining MVV_{WEAR}, one that relies on a different assumption. On this second option there exists another possibility for the measurement. Instead of assuming the average PE of a significantly large sample of propellants is zero, it may be more reasonable that the average MVV_{WEAR} value of a significantly large sample of howitzers is zero.

若此言不虛，仍有兩個選項：忽略 MVV 磨損並允許該值包含在經量測的 PE 中；或者以不同假設找尋確定 MVV 磨損的新方法。第二選項中，存在另一種量測的可能性。而不是假設大量發射藥樣品的平均 PE 值為零，反而 MVV 磨損平均值為零，更為合理。

Each howitzer coming off of the assembly line may fire slightly faster or slower than the standard howitzer, but the average change across many howitzers should be zero. In this assumption, there seems to be no reason for a negative bias like there is for the PEs. If this is the case, then a battery of six howitzers （or any larger unit） can fire one lot of propellant and compare each howitzer’ s PE measurement with the average of the

battery’ s PEs across all howitzers and the difference may be stored as the MVV_{WEAR} value. Again, an example best illustrates the principle. As before, assume that shooting strength is zero to simplify the problem. Also suppose that the battery has drawn one of the propellant lots with a an extreme PE of -15.0 m/s. Notice that the MVV_{WEAR} value of the howitzer will influence the PE, which produces a battery average PE of -15.0 m/s. Each howitzer then compares its measurement to the average in order to determine its MVV_{WEAR} value.

從生產線上下來的每門火砲，初速可能比標準稍快或稍慢一些，但是平均變量應該為零。在這個假設中，PE 似乎沒有理由產生負值。 如果是這種情況，那麼一個連六門砲（或其他更大的單位）可以發射同一批號發射要，然後將各砲測得 PE 值與全連平均值相比較，其差異可以存儲作為 MVV 磨損值。另以一個例子說明其中原理。先假設射擊強度為零以簡化問題。同時假設砲兵連選出某一批號發射藥，其最大 PE 為-15.0 m / s。請注意，火砲的 MVV 磨損值影響 PE，造成全連平均 PE 為-15.0 m / s。 然後各砲將其測量值與平均值做比較，以確定其 MVV 磨損值。

Shooting Strength	MVV_{WEAR} R	MVV_{LOT} (PE)	MVV
0.0	1.0	-15.0	-14.0
0.0	-1.0	-15.0	-16.0
0.0	0.6	-15.0	-14.4
0.0	-0.3	-15.0	-15.3
0.0	-0.6	-15.0	-15.6
0.0	0.3	-15.0	-14.7
Average:	**0.0**	**-15.0**	**-15.0**

In the example above, the first gun actually measure -14.0 m/s, but the battery average PE is -15.0 m/s. The gun can therefore imply that because it is shooting 1 m/s faster than the battery average PE, its MVVWEAR must be +1.0 m/s.

依據上述範例，第一門砲實測值為-14.0 m/s，但全連平均 PE 為 -15.0 m/s.，故該砲較全連平均值快 1 m/s，則該砲之 MVV 磨損為+1.0 m/s.。

Given that this method does not suffer the drawbacks of the current average PE assumption, it may be a more accurate method for determining MVV_{WEAR}, although empirical testing is required. It does suffer from a practical drawback however, namely that the DFCS does not have access to the information it would require for the calculation of MVV_{WEAR}. Because each howitzer operates independently, it does not know what PEs

the other howitzers are firing and therefore cannot determine the battery average PE. Furthermore, the validity of this method is reduced when less than six howitzers are able to fire and determine data. A method like this would have to use the AFATDS to receive the battery PE information and transmit that data to the howitzers.

該方法沒有目前採用平均 PE 假設的缺點，儘管需要實證測試，但仍可能是確定 MVV 磨損更準確的方法。然而在應用上則有其缺點，即 DFCS 並無計算 MVV 磨損所需的資訊。由於每砲獨立運行，因此無發獲悉其他射擊中火砲的 PE，因此無法確定全連的平均 PE。而且若射擊砲數少於六門，該方法的有效性降低。此一方法必須使用 AFATDS 來接收全連 PE 資訊，並將該數據傳輸給火砲。

A system change such as this, even if needed and desired, cannot be accomplished in the short term. For units concerned about PE issues and determining MVV_{WEAR}, there is an option available now to work around the problems. All new tubes should be 'calibrated' as quickly as possible. This is not a calibration in the manual sense, however, using the DA Forms 4982-1 and – 1-R. Instead, units should attempt to draw six different and relatively new lots of M231 and fire multiple rounds （ideally six） on charge 2L from each lot under controlled conditions in order to develop as accurate an MVV_{WEAR} value as possible.15 This calibration should also be conducted on howitzers with suspect MVV_{WEAR} values （it may be necessary in these cases to delete previous PE data）. By calibrating the MVV_{WEAR} value under controlled circumstances, both MVV_{WEAR} and future MVV_{LOT} values should be more accurate.

即使基於需要與期望，諸如此類的系統改變也不能在短期內完成。對重視 PE 與 MVV 磨損的單位，有一個選項可以解決問題。所有新砲管均應盡快實施「原級校正」。但這不是使用 DA Forms 4982-1 及-1-R 表人工原級校正的概念，而是選擇六個 M231 相對新的批號在受控條件下，以 2L 藥包射擊多發（理想情況下為 6 發），以便盡可能準確地算出 MVV 磨損值。[15]對 MVV 磨損數據可疑的或砲一可採用此一方法（此時可能必須刪除以前的 PE 數據）。經過在受控環境下校正的 MVV 磨損值，爾後的 MVV 磨損與 MVV 批號值都應該更準確。

In manual gunnery procedures, units were able to meet the third requirement for accurate predicted Fires, but were far less efficient than is now possible and those procedures were unable to isolate every variable that contributed to the total MVV.

[15] According to FTaB's PE Tables, Charge 2L's average PE is closest to 0 （+0.1 m/s） and, disregarding charge 1L, has the smallest standard deviation （1.5 m/s）. Charge 4H is next preferred charge for this procedure. Additionally, if problems with the M795 projectile family are validated, the M107 projectile family should be preferred.

Meeting the third requirement in the enhanced mode is far easier and faster than ever before, but the FA must ensure that reliance on the digital system does not create complacency in knowledge, skills and procedures, especially when there exists doubt on the validity of MV values which are so vital to accuracy in Fires. The enhanced MV system should be leveraged to employ accurate first round fire for effect for maneuver, especially with new lots of propellant. Maneuver commanders have little interest in the technical aspects of achieving first round fire for effect. As artillerymen, it is our duty to provide those effects no matter the conditions. Collecting the data is absolutely crucial to solving this problem and to more accurately meet the third requirement for accurate predicted fire.

在人工原級校正射擊程序中，部隊雖能滿足準確預測火力（譯註 6：不經試射效力射）的第三項要求，但效率遠低於現在的方式，且無法隔離導致 MVV 總值的每個變量。以加強版模式中滿足第三項要求比以往都更為容易且迅速，但野戰砲兵絕不能過度依賴數位系統，而忽略應有的知識、技能和程序，尤其在對 MV 值的有效性存在疑問時，這對火力的精準度至關重要。加強版的 MV 系統有助於支援戰鬥時第一發命中，尤其當使用新批號的發射藥時。戰鬥部隊指揮官對是否能第一發命中的技術層面，幾乎沒有任何興趣。但作為砲兵，無論條件如何，我們都有責任提供這些效果。蒐集充分數據，滿足精準射擊第三要求，對達成此一目標絕對重要。

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