ARL-SR-0417 ● MAY 2019

Initial Data Sets for Explorations in Long-Range Forecasting of Military Technologies

by Alexander Kott

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Office of the Director, CCDC Army Research Laboratory

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14. ABSTRACT

This report documents two initial data sets prepared by the author for exploratory investigations into feasibility of long-range trend analysis in the properties of military technologies. The data were extracted primarily from widely available open sources. The time period ranges from 1000 CE to 2015. The types of military weapon systems considered in these data sets are generally a few selected classes of direct-fire ground-mobile systems, such as infantry small arms (ranging from longbows and crossbows to modern assault rifles), cannons, tanks, tank destroyers, and so on. The records in the data sets cover, for example, the year when a system first appeared, the muzzle velocity of the projectile, the effective range of the weapon, the mass of the system, the motive power of the system, and so on. The report includes the data, notes on the sources and limitations of the data, and brief examples of possible uses of the data.

15. SUBJECT TERMS

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1. Introduction

The initial motivation for assembling these limited and exploratory data sets was to investigate whether the evolution of certain classes of weapons might exhibit an exponential trend.

Exponential growth is a commonly found form of long-term trends in advances of a technology (Nagy et al. 2013). This form of growth implies an increase in a system's utility or some figure of merit (FoM) by a constant fraction per unit of time so that the growth is proportional to the value of the utility achieved at the given time. Exponential trends in technology growth have been observed for many decades and explained in part by the action–reaction behaviors of market competitors (Seamans 1969). Although observed in multiple technologies (e.g., Nagy et al. [2013] describe such exponential laws for 62 different technologies), a particularly well-known example is Moore's law (Schaller 1997), so much so that exponential trends in technology are often called simply a generalized Moore's law (Sood et al. 2012; Nagy et al. 2013).

The data for this report were extracted primarily from widely available open sources. The time period ranges from 1000 CE to 2015. The types of military weapon systems considered in these data sets are generally a few selected classes of direct-fire ground systems, such as infantry small arms (ranging from longbows and crossbows to modern assault rifles), cannons, tanks, tank destroyers, and so on. The records in the data sets cover, for example, the year when a system first appeared, the muzzle velocity of the projectile, the effective range of the weapon, the mass of the system, the motive power of the system, and so on.

As illustrated later in this report, it is indeed possible to detect a form of Moore's law in the evolution of military systems. It is likely that these data sets could be used for other purposes associated with the study of trends in the evolution of the systems covered in the data or serve as an initial point for expanded data sets for other uses.

This report is organized as follows. Section 2 discusses the limitations and disclaimers associated with the data sets documented here. Section 3 offers a couple of illustrative examples that show some possible uses of the data sets. Section 4 presents data and notes on sources pertaining to infantry small arms. Section 5, in a similar fashion, describes several classes of mobile direct-fire systems. The data set presented in Section 5 includes the data in Section 4 with some additional information. Finally, Section 6 offers a few conclusions and describes potential future work.

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2. Limitations, Sources, and Disclaimers

The data sets presented in this report are limited in a number of ways.

First, only a few classes of systems are considered. For example, Section 6 does not consider machine guns or automatic cannons. The data are primarily for Western European and US weapons, and do not represent other parts and cultures of the world, although a few Byzantine, Turkish, Russian, and Japanese weapons happen to be included. To be sure, this report does not and could not cover exhaustively all weapons of the last millennium; my selection was largely based on the ready availability of data and the hope is that the sample is sufficiently representative.

The availability and quality of the data sources were always a challenge. In many cases, particularly for weapons of periods prior to 19th century, the data are limited and contradictory. Assumptions, conjectures, and interpretations were often required. The data for modern weapon systems, of the last 20–30 years, are often classified. As such, the open sources are of highly uncertain accuracy.

A broad range of sources were consulted. Historic studies of technology evolution focused on a particular period often provide suitable quantitative details. For example, Gabriel and Metz (1991) review the evolution of arms and warfare of antiquity, with attention to quantitative description of the performance and capabilities of the period's armies. For the medieval period, Williams (2003) offers a unique study of armor along with weapons' evolution engendered by advances in armor. Duffy (1988) covers warfare technologies of the 18th century. Lewis (1956) offers a detailed review of small arms in the United States between the Revolutionary War and the Civil War, while Kerr (2015) explores how the emergence of rifles as a primary weapon of infantry in the Civil War, and their then-novel capabilities, influenced the tactics of the conflict.

The nature of this report necessitated special attention to studies focused on characteristics of particular classes of weapons, such as McLachlan (2010), which focuses on handgonnes; Phillips (1999), which explores how harquebuses replaced the longbow in England; and Reid (2016), which studies the last century and a half in the long history of muskets. Krenn et al. (1995) is an example of exceptionally valuable work in which physical features and characteristics of arms are determined by rigorous testing of examples preserved in museums. Their work covers weapons of several centuries, including the 18th century, while Roberts et al. (2009) concentrate on the capabilities of 18th-century muskets. For modern weapons, the magisterial Ezell (1983) offers a broad overview of small-arms developments in the 20th century and exhaustive details on the design and characteristics of hundreds of individual weapons around the world.

Unconventional sources were of great importance as well and had to be used on a number of occasions. For example, much quantitative data about historic weapons come from re-enactors and enthusiasts of reproduction weapons, not from academic researchers. When necessary, and when I judged them credible, I used unconventional sources such as Internet-posted videos that report tests of replica or antique weapons.

Wikipedia was used unapologetically and extensively, especially considering that Wikipedia articles on firearms and other weapon systems are served by a vigorous community of weapons enthusiasts. I found such articles generally more accurate, complete, and rigorously curated than any other single source on small arms. Nevertheless, in most cases, the data of Wikipedia were cross-checked against such sources as Jane's Defence online databases (Ogorkiewicz 1970; Blair 1983; Ezell 1983; Hogg 1985; Halberstadt 2002; Bailey 2004; Norris 2011).

In general, however, the sources used for this report are uneven in quality and degree of authority. In a number of cases, assumptions and estimates are quite crude and should be revisited in future work. As such, the data in this report should be used with caution and certainly not for the purposes of obtaining authoritative data for any individual system. Still, I assess that the data from different sources are generally consistent within any given historical period and portray plausible trends over time. This should give a researcher a degree of confidence in the data sets. The value of these data is not in individual data points but in the data ensemble. To put it differently, the value is not in an individual pixel but in the overall picture.

3. Illustrative Uses of the Data

This sections offers two illustrative examples of how the data sets could be used. To be sure, these examples are very brief, preliminary in nature, and intended here strictly as illustrations.

Figure 1 is based on the data set in Section 4. It shows that with an appropriate formulation of a FoM for infantry small arms, it is possible to approximate the evolution of the FoM over a very long period (about 800 years) as a quadratic function of time (i.e., a variation on Moore's law). Such a trend and the underlying FoM could be useful for forecasting purposes.

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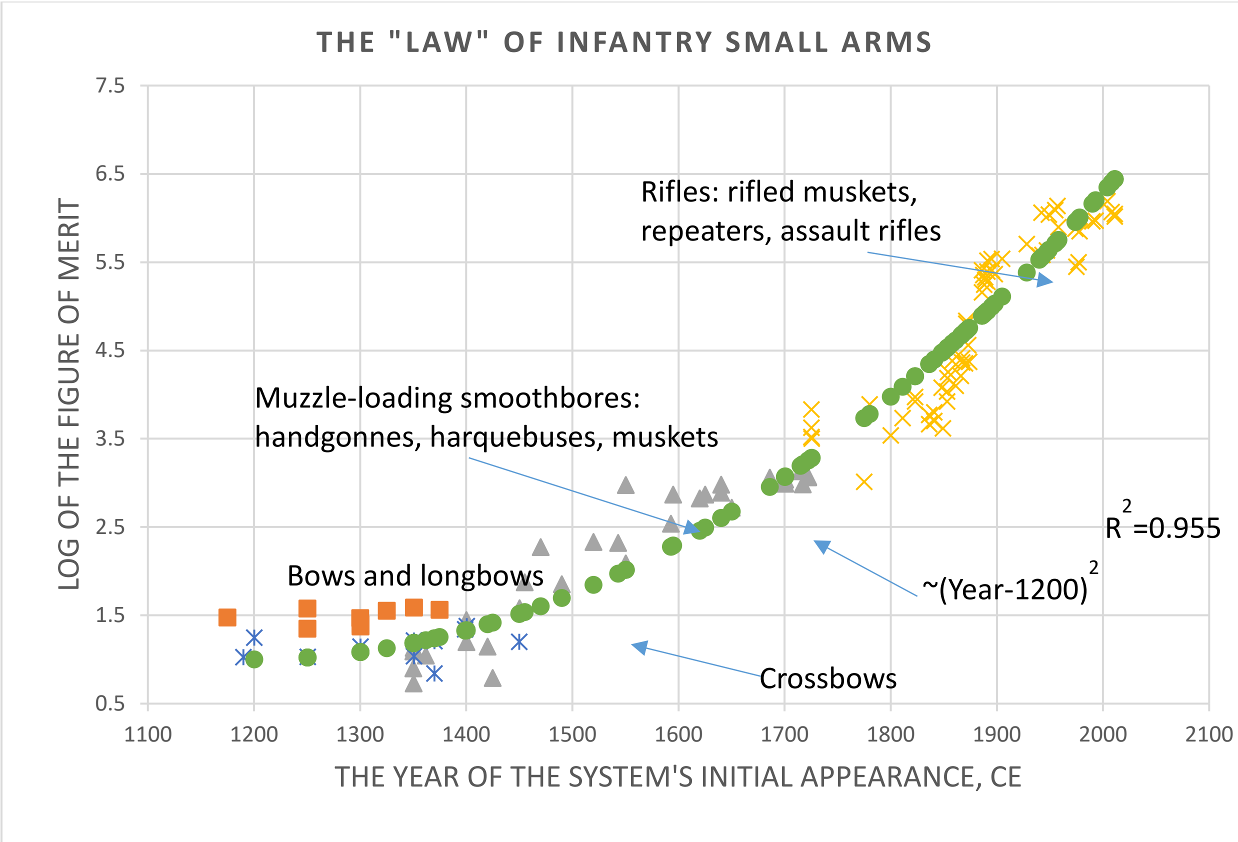

Fig. 1 The log of the FoM can be closely approximated as a quadratic function of time, ~(year-1200)^2. Here the FoM is chosen as ~$V^2 D^{2.3} M^{0.61} R^{0.39}$, where V is the muzzle velocity, D = maximum effective range, M = projectile mass, and R = maximum rate of fire. The R^2 is 0.955 for the data in years 1200–2015.

Figure 2 similarly shows that a suitable FoM for multiple mobile direct-fire weapons systems (ranging from an infantryman to a tank) can also be approximated as a function of time.

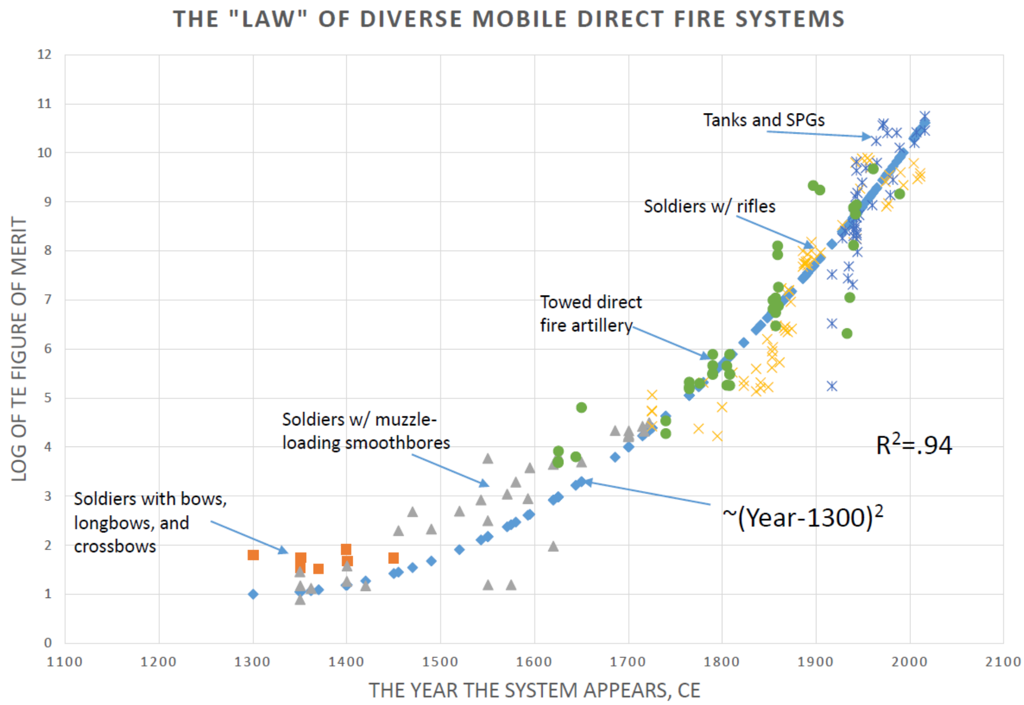

Fig. 2 The log of the FoM is closely approximated as a quadratic function of time, ~(year-1300)^2. Here the FoM is chosen as ~(KE×R/HP)×D$^{2.4}$*S$^{1.7}$/C$^{1.9}$, where KE is the muzzle energy of the projectile, R = maximum rate of fire, HP = the motive power of the system, D = maximum effective range, S = characteristic speed offroad, and C = crew size of the system.

I plan to present the details of such studies in future publications.

4. Data Set of Infantry Small Arms

In Section 4.1 is a table (Table 1 in Section 4.1) that includes all the data used in deriving the primary results of this report. In Table 1, the second column lists the notes describing the sources and assumptions associated with the data.

Next, Section 4.2 is a collection of notes to which Table 1 refers, followed by bibliographic references. Note the numbers are not necessarily consecutive—there are gaps in the numbers.

Each data point is described by a tuple of the form {*T, M, R, D, V*}, defined as follows:

- *T* is the approximate year in which the weapon was introduced or designed. I limit the period under consideration to 1000 CE to 2015. In most cases sources exist that report the date of the weapon's design or introduction into service, but in some cases, I had to resort to assumptions.

- *V* is the projectile velocity at the moment of separation from the weapon (i.e., the arrow velocity as it exits the bow or the bullet velocity when it exits the muzzle). In most cases, sources exist to provide these data. In some cases, the kinetic energy (KE) and the mass of the projectile were known, and the velocity was calculated from these data. The velocity of the projectile is an important characteristic of a weapon. It influences the amount of KE that is available to incapacitate the adversary. It also determines, in part, how flat the trajectory of the projectile is, and thereby, the potential accuracy of the weapon. For the purposes of this data set, I do not consider so-called "terminal effects"—the characteristics and behavior of the projectile as it interacts with the target. An attempt to consider terminal effects explicitly would require a level of detail that goes far beyond what is appropriate for trend-based forecasting.

- *D* is the maximum effective range (i.e., the distance at which an infantryman can fire the weapon with an acceptable probability of hitting and disabling the targeted adversary). This is another very important characteristic of a weapon. By maximizing this distance, the infantryman increases the probability of their own survival while fulfilling their mission of defeating the adversary. In the US military, the official definitions of maximum effective range are not particularly clear or consistent (DA 2004). For the purposes of this data set, I recognize the weaknesses of existing definitions and interpret them to imply that a typical infantryman in typical operational conditions, when firing the weapon from a distance *D*, should have 50% probability of hitting the target (presumably, a person-sized target) and disabling the adversary. For modern weapons, effective range data are available from a variety of sources, including official government sources, although disagreements exist regarding their accuracy (Ehrhart 2015). For weapons introduced prior to the 20th century, the data are difficult to find and are widely inconsistent.

- *M* is the mass of the projectile. I include this in this data set for several reasons. It influences the KE of the projectile, and thereby, the ability to disable the adversary. A higher mass also reduces the impact of wind on the trajectory of the projectile, and thereby, increases the accuracy of the weapon. However, a higher mass of a projectile also has undesirable ramifications; for example, it reduces the number of projectiles (or rounds) that the infantryman can carry into a battle. It also increases the recoil (i.e., the backward blow that a gun delivers to the body of the shooter when the gun discharges). These are merely examples of the issues related to the mass of a projectile; in general, many complex dependencies exist. The data for the mass of projectiles (arrows, bolts, bullets) are typically available and are largely consistent.

- R is the maximum rate of fire (i.e., the maximum number of projectiles per minute that an infantryman can fire from the weapon). For many weapons, such as bows or muskets, the rate of fire is on the order of 1–10 per minute, including the time required to reload and re-aim the weapon. For fully automatic weapons, this rate (called the cyclic rate of fire) may exceed 1000 per minute, although prolonged firing at that rate may overheat and destroy the weapon. R is an important characteristic of a weapon for a number of reasons. For example, it enables the infantryman to maximize the chances of hitting the adversary when they are visible for a short time. An alternative would be to use the sustained rate of fire, that is, the rate that at which projectiles can be fired without overheating the weapon (e.g., in case of an automatic rifle) or overtiring the shooter (e.g., in case of a longbow), but I elected to focus on the maximum rate of fire. The data are generally available, although not always consistent for historical weapons.

4.1 Table of Data

Table 1 include the data set for infantry small arms.

Table 1 Data set of infantry small arms

Weapon	Notes	Year of introduction (CE)	Projectile mass (kg)	Rate of fire, rounds per min	Effective range (m)	Muzzle velocity (m/s)
Byzantine bow (1)	45a	1000	0.0320	5	75	75
Byzantine bow (2)	45b	1000	0.0600	5	75	55
Bow	46a	1000	0.0358	5	75	60
Longbow	76, 76d	1050	0.0536	5	75	66
Longbow	8, 76 (p. 48)	1066	0.1020	5	75	47
Longbow	76a	1100	0.0420	5	75	69
Longbow	76, 76d	1150	0.0578	5	75	63
Crossbow d-w 600 lb	3, 3a	1190	0.0600	1	75	45
Turkish warbow	5	1100	0.1002	5	75	40
Turkish warbow	5	1125	0.0691	5	75	48
Turkish warbow	5	1150	0.0478	5	75	56
Turkish warbow	5	1175	0.0338	5	75	65
Crossbow	52, p. 920	1200	0.1000	2	75	43
Longbow	76, 76d	1250	0.0744	5	75	58
Longbow	51a	1250	0.1300	5	75	37
Crossbow	76b	1251	0.0600	2	75	39
Longbow	51b	1300	0.1150	5	75	45

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Table 1 Data set of infantry small arms (continued)

Weapon	Notes	Year of introduction (CE)	Projectile mass (kg)	Rate of fire, rounds per min	Effective range (m)	Muzzle velocity (m/s)
Crossbow	51c	1300	0.0600	2	75	45
Yew longbow	52, p. 918-919	1300	0.0500	5	75	53
Yew longbow	52, p. 918-919	1301	0.0900	5	75	43
Longbow	76, 76d	1325	0.0866	5	75	54
Loshult handgonne	51, p. 9	1350	0.1840	0.5	25	142
Handgonne	51, p. 69	1350	0.0410	0.5	25	180
Handgonne	52, p. 921-922	1350	0.0400	0.5	25	149
Handgonne	52, p. 921-922	1351	0.0385	0.5	25	239
Crossbow d-w 750 lb	3, 3a	1351	0.1000	1	75	39
Longbow	76a	1351	0.1080	5	75	52
Crossbow 1000 lb	82	1351	0.0960	1	75	48
Handgonne	26	1362	0.0500	0.5	25	200
Crossbow 740 lb	4	1370	0.0354	1	75	42
Crossbow 740 lb	4	1370	0.0354	1	75	64
Longbow	76, 76d	1375	0.0959	5	75	53
Crossbow d-w 1500 lb	3, 3a	1399	0.1000	1	75	55
Handgonne	52, p. 921-922	1400	0.0400	0.5	25	255
Handgonne	52, p. 921-922	1400	0.0390	0.5	25	343
Crossbow	52, p. 919-920	1400	0.0800	0.5	75	70
Hussite gun	52, p. 921	1420	0.0352	0.5	25	250
Handgonne	51, p. 69	1425	0.0410	0.5	25	159
Huckbut	51, p. 75	1450	0.0232	1	50	181
Crossbow, 1090 lb	3, 3a	1450	0.1000	1	75	47
Arquebus	42	1455	0.0278	1	50	240
Harquebus	51, p. 26-27	1470	0.0160	1	50	450
Handgonne	51, p. 69	1490	0.0410	1	25	469
Matchlock harquebus	51, p. 75	1520	0.0122	1	50	521
Tanegashima	81	1543	0.0374	1	50	366
Arquebus	76, p. 398	1550	0.0200	1	50	340
Musket	76, p. 398	1550	0.0380	1	75	482
Wheellock RG117	47	1593	0.0108	1	75	427
Wheellock RG33	47	1595	0.0300	1	75	456
Matchlock LG1514	47	1620	0.0174	2	75	449
Wheellock RG272 rifled	47	1625	0.0321	2	75	392

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Table 1 Data set of infantry small arms (continued)

Weapon	Notes	Year of introduction (CE)	Projectile mass (kg)	Rate of fire, rounds per min	Effective range (m)	Muzzle velocity (m/s)
Musket English Civ War	83	1640	0.0289	2	75	415
Musket English Civ War	83	1640	0.0407	2	75	415
Musket	46, p. 70-71	1650	0.0410	2	75	306
Flintlock STG1318	47	1686	0.0309	2	75	494
Musket	12	1700	0.0198	2	75	550
Flintlock musket STG1287	47	1700	0.0275	2	75	474
Flintlock STG1316	47	1701	0.0321	2	75	451
Flintlock STG1317	47	1701	0.0343	2	75	467
Flintlock E28	47	1715	0.0299	2	75	543
Charleville	25, 71, 72	1717	0.0243	3	75	450
Brown Bess	16, 14, 48, 71, 72	1722	0.0329	3	75	450
Brown Bess	48, 71, 72	1722	0.0321	3	75	457
Long rifle - 1	19	1725	0.0107	2	200	366
Long rifle - 2	19	1725	0.0062	2	200	488
Kentucky rifle	79, p. 181	1725	0.0083	2	200	566
Pennsylvania rifle	79, p. 242	1725	0.0029	2	200	533
Flintlock musket STG1288	47	1775	0.0260	3	75	455
Jaeger rifle	77	1780	0.0189	2	200	471
Baker rifle	66, 72	1800	0.0226	1.5	200	315
M1819 Hall rifle	60	1811	0.0140	8	200	330
Hawken rifle, cal. 53	79, p. 171	1823	0.0137	2	200	571
Hawken rifle, cal. 50	79, p. 180, p. 187	1823	0.0115	2	200	569
Dreyse needle gun	60	1836	0.0250	6	200	305
Brunswick rifle	60, 67, 69	1836	0.0312	2	200	312
Mississippi rifle M1841	60	1841	0.0324	2	200	360
1841 Mississippi rifle	79, p. 236	1841	0.0343	2	200	315
Sharps rifle	60	1848	0.0307	10	200	370
Fusil Minie	60, 68	1849	0.0324	3	200	270
Enfield 1853 rifled musket	60	1853	0.0324	3	270	270
Enfield 1853 rifled musket	69	1853	0.0451	3	270	277
Enfield 1853 rifle	79, p. 228	1853	0.0327	3	270	364
Whitworth rifle	79, 60	1854	0.0317	3	270	398
Chassepot	60	1858	0.0250	8	270	410

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Table 1 Data set of infantry small arms (continued)

Weapon	Notes	Year of introduction (CE)	Projectile mass (kg)	Rate of fire, rounds per min	Effective range (m)	Muzzle velocity (m/s)
Springfield 1861	17	1861	0.0189	3	270	390
Winchester	21	1866	0.0131	20	270	343
Werndl-Holub	53	1867	0.0240	7	270	439
Vetterli	60	1867	0.0220	7	270	428
Berdan	23	1870	0.0198	7	270	437
Martini-Henri	2, 53	1871	0.0310	12	370	397
Mauser 1871	53	1871	0.0250	12	370	440
Springfield 1873	53	1873	0.0325	15	270	410
Gras rifle	22	1874	0.0249	7	250	455
Lebel rifle	60	1886	0.0150	21	400	610
Austrian Mannlicher	2	1886	0.0158	20	500	621
Lee-Metford	2, 60	1888	0.0116	20	500	564
Rubin	2	1889	0.0139	15	500	601
Belgian Mauser	2	1889	0.0142	15	500	620
Mosin-Nagant	60	1891	0.0097	15	500	865
Mosin-Nagant	2	1891	0.0138	15	500	588
Carcano	2	1891	0.0105	15	500	730
Lee-Enfield	24	1895	0.0123	25	500	744
Mannlicher M1895	60	1895	0.0160	20	500	620
Arisaka Mauser	2	1887	0.0105	15	500	697
Mauser 98	60	1898	0.0146	15	500	639
Mauser w/ Spitzgeschoss	2	1905	0.0099	15	500	879
M1 Garand	60	1928	0.0110	40	500	853
SVT-40	60	1940	0.0097	25	500	835
Sturmgewehr 44	60	1942	0.0081	550	600	685
Gewehr 43	60	1943	0.0128	25	500	776
AK-47	29b	1947	0.0079	600	380	710
M-14	39	1949	0.0096	700	460	830
G3	60	1955	0.0110	550	500	800
M-16	29b	1957	0.0036	800	550	990
FN FAL	47	1958	0.0095	700	400	835
AK-74	60	1974	0.0034	600	500	880
SA 80	60	1975	0.0036	700	300	940
Steyr	47	1977	0.0036	700	300	990
FA MAS	35	1978	0.0036	1000	400	993
G36	60	1990	0.0036	750	500	920
M-4	40	1993	0.0041	700	500	900
FN SCAR-H	60	2004	0.0110	600	600	714
M-27	41	2008	0.0041	700	550	900

Table 1 Data set of infantry small arms (continued)

Weapon	Notes	Year of introduction (CE)	Projectile mass (kg)	Rate of fire, rounds per min	Effective range (m)	Muzzle velocity (m/s)
AK-12	60	2011	0.0036	700	550	880
AK-15	60	2011	0.0080	700	550	715
MP 40	60	1938	0.0075	550	100	400
PPSh-41	60	1941	0.0055	900	125	488
Heavy musket, rifled G284	47	1571	0.0383	1	75	482
Heavy musket, rifled G358	47	1580	0.0491	1	75	533
Springfield M1795	60, 70	1795	0.0298	3	75	370
Crossbow d-w 150 lb	3, 3a	1150	0.0600	3	75	22
Handgonne	52, p. 920	1350	0.0500	0.5	25	100

4.2 Notes on Sources

Note 1: On Effective Range

From FM 101-5-1 (DOA 2004):

“Maximum effective range—(DOD, NATO) The maximum distance at which a weapon may be expected to be accurate and achieve the desired effect. [*Data compiler’s note: The NATO definition replaces “effect” with “result.”*] (Army) The distance from a weapon system at which a 50% probability of target hit is expected, or the tracer burnout range.”

Literature sources other than those for weapons of the last 150 years are generally unclear and contradictory regarding the effective range or use a less exacting definition than the one above. Multiple notes offer data and opinions on the effective range of various weapons—specifically, Notes 19, 42, 45, 46, 47, 48, 50, 51, 54, 55, 57, 59, 61, 62, 65, 72, 73, 74, and 75. Based on all such references, I elected to use the following numbers (in meters), unless a source exists that appears to give data in accordance with the modern definition:

- Bows, longbows, crossbows—75
- Handgonnes—25
- Harquebus—50
- Musket 16th century—50
- Musket 17th–18th century—75

- Musket 19th century—75
- Muzzle-loading ball rifle—200
- Muzzle loading Minie rifle—270
- Breech loading rifles of 19th century—270
- Rifles post 1850s—as found in the corresponding sources, see the notes specified in Table 1 for the particular rifle.

Note 1a: On Rates of Fire

The literature tends to be silent or contradictory on the rates of fire for periods earlier than approximately 1600 CE. Multiple notes offer data and opinions on effective range of various weapons—specifically, Notes 42, 46, 47a, 50, 61, 62, 67, 68, 72, and 73. Based on all such references, I make the following, admittedly rather crude, assumptions, unless specific data are available in the literature. All numbers are in shots per minute.

- Bows and longbows—5
- Early crossbows 10th–11th century—3
- Crossbows of 12th–13th century—2
- Crossbow 14th century—5
- Handgonnes—0.5
- Harquebus—1
- Musket 16th century—1
- Musket 17th–18th century—2
- Musket 19th century—3
- Muzzle-loading rifle—1
- Muzzle loading Minie rifle—3
- Rifles post 1850s—as specified in literature

Note 2

From Blair (1983) (Note: m = mass and v = velocity):

- p. 181: In the early 19th century, the military rifle was used by picked men who rarely fired beyond 300 yd.

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- p. 260–261: Martini-Henry, year 1874, m 480 gr, v 1300 fps
- p. 268: Lee-Metford, year 1888, v 1850 fps
- p. 269: Rubin rifle, year 1889–1891, m 215 gr, v 1970 fps
- p. 269: Austrian Mannlicher, year 1886–1890, 8-mm bore, v 2035 fps
- p. 270: Belgian Mauser, year 1889, 7.65 mm, m 219 gr, v 2034 fps
- pp. 271–280:
    - 1895 Mannlicher, 8 mm, m 244 gr, v 2034 fps
    - 1891 Carcano, 6.5 mm, m 163 gr, v 2395 fps
    - 1890 Romanian Mannlicher, m 159 gr, v 2400 fps
    - 1898 German Mauser, m 227 gr, v 2093 fps
    - 1905, pointed bullet Spitzgeschoss, v 2882 fps, same as the 1898 Mauser. [*Data compiler's note: According to Wikipedia, m 153 gr.*]
- p. 281: 1891 Mosin-Nagant, m 214 gr, v 1927 fps.
- p. 281: 1897 Arisaka Mauser, m 163 gr, v 2286 fps.

Note 3

From Loades (2018):

- p. 19: 12th century, wooden laths, draw weight of 150 lb for the average Soldier. Draw 4–5 inches.
- p. 23: End of the 12th century, composite lath, draw weight of 200–600 lb, higher efficiency than the wooden lath.
- p. 25: Mid to end of the14th century, steel lath, draw weight of 750 lb, and up to 1500 lb.
- p. 30: Eight bolts in 5 min was reasonable, based on modern experiments.
- p. 32: A particular crossbow in a museum collection was tested at 1090 lb. Perhaps 15th century (from Paterson [1990]).

Note 3a

I estimate the "muzzle" energy of the bolt assuming the draw weights given in Note 3, with a draw length of 5 inches and an efficiency of 35%. I assume a bolt mass of 100 g for the 14th and 15th centuries, and 60 g for earlier centuries.

Note 4

Paterson (1990) presents test data for a crossbow spanned with a cranequin, with a draw weight of 740 lb; the velocity of the bolt was 138.7 fps and the bolt weight was 1.25 oz (35.4 g). Based on Note 76 (p. 122), I assume 1370 as the date of this weapon. Assuming a draw length of 5 inches, I calculate the efficiency of this crossbow as quite low, only 15%. Assuming a more typical efficiency of 0.35, I obtain a higher velocity, 64.3 mps. I use both of these data points.

Note 5

From Karpowicz (2006):

A Turkish warbow with a draw weight of 72.1 lb at a 28-inch draw-length with an arrow weight of 1548 gr showed 131.2 fps; 1067 gr—156.2 fps; 739 gr—185.2 fps; and 522 gr—213.2 fps.

A warbow with a draw weight of 75.5 lb at a 28-inch draw-length showed approximately the same results.

Based on Note 78, I assume these data are representative of the Turkish composite bows developed in the 12th century, and I assigned dates to them ranging from 1100 to 1175. I also assumed that because achieving a greater range was a major objective of the Turkish bowmen, higher velocities are likely to correspond to later dates.

Note 6

https://en.wikipedia.org/wiki/Crossbow.

Note 8

https://en.wikipedia.org/wiki/English_longbow.

Note 9

https://en.wikipedia.org/wiki/History_of_crossbows.

Note 12

https://en.wikipedia.org/wiki/Musket.

Note 14

The weight of the musket ball is calculated from the diameter and density of lead. When the diameter of the ball is unknown, assume a windage of 0.05 inch.

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Note 15

https://en.wikipedia.org/wiki/Arquebus.

Note 16

https://en.wikipedia.org/wiki/Brown_Bess.

Note 17

https://en.wikipedia.org/wiki/Springfield_Model_1861.

Note 18

https://en.wikipedia.org/wiki/Springfield_Model_1840_flintlock_musket.

Note 19

https://en.m.wikipedia.org/wiki/Long_rifle.

For this report, I assume an effective range of 200 m; significantly more than for a musket, but somewhat less than for the more modern rifles of the mid-19th century. Also see Blair (1983, p. 139) regarding Jaeger-type rifles being accurate "up to 200 yd".

Using data from this source, I assumed two common cases: 0.4 caliber with a 1600-fps muzzle velocity and 0.48 caliber with a 1200-fps muzzle velocity.

Note 20

https://en.m.wikipedia.org/wiki/Rifle.

Note 21

https://en.m.wikipedia.org/wiki/Winchester_rifle.

Note 22

https://en.m.wikipedia.org/wiki/11×59mmR_Gras.

Note 23

https://en.m.wikipedia.org/wiki/Berdan_rifle.

Note 24

https://en.m.wikipedia.org/wiki/Lee–Enfield.

Note 25

https://en.m.wikipedia.org/wiki/Charleville_musket.

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Note 26

http://albrechts.se/handgonnes-and-cannons-of-the-middle-ages/.

This source appears to present competent tests of replica handgonnes. It suggests a muzzle energy of about 1000 J and a velocity range of 150–250 m/s. I use 200 m/s.

Note 28

Early black powder produced velocities of only 120 m/s.

See https://en.m.wikipedia.org/wiki/Muzzle_velocity.

Note 29b

https://en.wikipedia.org/wiki/Comparison_of_the_AK-47_and_M16.

Note 35

https://en.m.wikipedia.org/wiki/FAMAS.

Note 39

https://en.wikipedia.org/wiki/M14_rifle.

Note 40

https://en.wikipedia.org/wiki/M4_carbine.

Note 41

https://en.wikipedia.org/wiki/M27_Infantry_Automatic_Rifle.

Note 42

From Dupuy (1982):

- p. 93: Earliest handguns caliber between 25 and 40 mm. Less than 10 inches long. Very poor accuracy.
- p. 94: Improved with corned powder in the 15th century. Effective range barely 50 yd.
- p. 95: Arquebus. Ball somewhat less than an ounce. Muzzle velocity 800 fps. Range 100–200 yd.
- p. 96: Earliest muskets bullets 10–14 to the pound. Effective range well under 200 yd; 2 rounds in 3 min was exceptionally good.
- p. 130: In 1600s, ball 12–14 to the pound.

- p. 146: By 1700, ball 18–20 to the pound.
- p. 150: Prussian soldiers started fire at 100 paces.
- p. 166: Brown Bess has an effective range of 300 yd but accurate enough to hit a man only at about 100 yd.

Note 45: Byzantine Bows and Arrows

From O'Rourke (2010):

- p. 13: medium weight arrow was 32 g.
- p. 15: Eighty yards is the limit of any archer for hitting a specific target.
- p. 17: A longbow with a medium pull of 100 lbf could only defeat a normally armored opponent at below 50 m.
- pp. 18–19: A war arrow was about 60 g; a realistic pull is 50–70 lbf.
- p. 29: Arrow length was 27–28 inches.

Note 45a

Based on Note 45, the muzzle KE (ME) is estimated as assuming a bow efficiency of 0.85, pull of 70 lbf, and draw length of 27 inches (i.e., 0.5 × 0.85 × 70 × (27/12) × 1.356 = 90.8 J); with a 32-g arrow, the velocity is 75.3 mps.

Note 45b

Similar to Note 45a, except here I assume a 60-g arrow.

Note 46

From Gabriel and Metz (1991):

- p. xviii: Experiments used 100-lb pull composite bow. Ancient composite bow was capable of 125 lb of pull.
- p. xix: Experiments involved man 6 ft tall, 180 lb. Obtained velocity from stroboscopic photos and calculated KE. Used armor of 2-mm bronze and iron (8% carbon content).
- p. xx: Arrow was 553 gr, 29 inches long. Velocity was 196 fps. Fired at 10 yd by expert archers. With armor, 75.5 ft-lb were required for a sufficient wound.
- p. xxi: At 300 yd, could hit a maniple-sized target (50 yd front, 20 yd depth) 50% of the time. From moving track could hit aa person-sized target 80% of the time at 10–20 yd.

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- p. 9: Regular (noncomposite bow) could kill at 50–100 yd, but not with any armor, even leather.
- p. 59: Table of performance characteristics for several weapons.
- p. 63: Energy required to penetrate bronze and iron armor, for several weapons.
- p. 68: After firing 10–12 arrows at maximum pull, an archer cannot perform well; 5 arrows a minute is unrealistic expectation.
- p. 70–71: Muzzle loading musket of the 18th century; fired a lead ball of 0.75 inch diameter at a muzzle velocity of 1020 fps. Only 16% of rounds could hit a formation. Only 0.5% of rounds could hit an individual Soldier.

Note 46a

Based on Note 46, I assume an arrow of 553 gr (35.8 g) and a velocity of 196 fps (59.8 mps).

Note 47

From Krenn et al. (1995):

- p. 101: Early modern small arms under the best of circumstances were extremely inaccurate. Bullets lost most of their KE within 30–50 m of flight. Provides table of experimental data for multiple muskets, including year of manufacturing, bullet mass, and muzzle velocity.
- p. 106: Moritz Thierbach, writing in 1866, summarized several Prussian, Bavarian, and French tests as if they had been one standardized effort involving 60 shots at target approximately 100 ft (30 m) long by 7 ft (2.13 m) high. Thierbach calculated that from a distance of 75 m, only 36 shots (60%) penetrated the target; from 150 m, 24 shots (40%); from 225 m, 15 shots (25%); and from 300 m, only 12 bullets (20%) found their mark. The Graz tests suggest Thierbach may have been optimistic in his estimates.
- p. 107: While firearms were capable of inflicting horrible wounds, this ability was restricted to very close-range fire. [*Data compiler's note: This seems to suggest that about 30 m was the realistic effective range?*]

Note 47a

From Ostrowski (2010):

- p. 513: Mounted archer with composite bow could shoot 6–15 shots a minute, with an effective range (??) of 350–500 m.
- p. 518: From the 16th-century Tudor warship *Mary Rose*, sunk off Spithead in the Solent channel 19 July 1545: 172 long bows and 3,969 arrows a draw weight of between 100 lb (45 kg) and 180 lb (81.5 kg), with the largest group being in the 150–160 lb (68–72.5 kg) range.

Note 48

From Roberts et al. (2009):

- Studied Brown Bess, principal weapon of British infantry in 18th century; conflicting opinions.
- By a colonel in late 18th century: "A Soldier's musket, if not exceedingly ill-bored, as many are, will strike a figure of a man at 80 yd".
- The weapon weighed around 10 lb 8 oz (4.7 kg) and had a 46-inch length barrel with a 0.75-inch (1.87-cm) bore diameter. The shot fired was 14-bore lead.
- Robins also conducted research on ballistics, published in 1742, which along with Mordecai's work, show that muzzle velocities of 1500 fps or 457.2 m/s were being obtained from muskets.
- Accuracy of the Brown Bess was, as with other muskets, low. The effective range [*Data compiler's note: By what definition??*] is often quoted as 100 yd.
- 14-bore lead shot. The closest obtainable match to this was 0.691 inches in diameter.
- Experiments show massive damage done to a body-like target even at 150 yd, and even against armor.

Note 50

From Phillips (1999):

- Longbows from Henry VIII's *Mary Rose*, which sank in the Solent off Portsmouth in 1545, has allowed for extensive testing. Tests have suggested that a bow of 70-lb draw, firing a heavy bodkin-type arrow, had a potential effective range [*Data compiler's note: Defined as ??*] of between 150 and

200 m, but against an armored target such fire would be far from lethal. Test arrows failed to penetrate 3 mm of plate armor (the thickness of a good breast plate or helmet) at just 10 m. Arrows could penetrate 2 mm of armor at the same distance, but not with enough force to cause a serious wound.

- Humfrey Barwick (a witness generally hostile to archery) allows the bow a rate of fire of six arrows every 40 s, compared to the arquebusiers one shot in the same period. Fire at this rate could neither be sustained nor accurate.
.

Note 51

From McLachlan (2010):

- p. 8: Milemete gun of about 1330. A reconstruction of the smaller of the Milemete cannons by the Royal Armouries fired an arrow weighing 1.8 kg (4 lb) to a range of about 150 m. The arrow was 1350 mm (53 in) long with a 38-mm bore. A charge of only 230 g (8 oz) of gunpowder was found to work best.
- p. 9: A replica of the Loshult gun [*Data compiler's note: mid 1300?*] was in 1999 also tested by the Royal Armouries and a team of Danish researchers. used four early recipes with different proportions of saltpeter, sulphur, and charcoal. A charge of 50 g (1¾ oz) fired a 184-g (6½-oz) lead ball. A reproduction of an early gun arrow was also used with either a 20- or 50-g charge. The muzzle velocity rose with the proportion of saltpeter. Gunpowder with 50% saltpeter shot a lead ball with an average muzzle velocity of 110 m/s, going up to 142 m/s for powder containing 75% saltpeter. The balls achieved ranges from 275 to 945 m, the average being 630 m. Two arrow shots had lower muzzle velocities, 63 and 87 m/s, probably due to the looser fit of the projectile within the barrel, yet the arrows still achieved a range of 205 and 360 m.
- p. 10: Test firings were also conducted with modern commercial powder. Commercial meal powder had an average muzzle velocity of 151 m/s, commercial rifle powder 254 m/s, and commercial cannon powder 227 m/s.
- pp. 26–27: By 1470s, modern tests show a muzzle velocity of 450 m/s. Bullets became smaller, generally, 12–15 mm rather than the 20–25 mm of the hackbut, but much deadlier.
- p. 55: A rack of four heavy hook guns from the late 15th/early 16th century. Total length 1515 mm, barrel length 920 mm, caliber 25.5 mm. Total length 1510 mm, barrel length 885 mm, caliber 25 mm. Total length 1433 mm,

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barrel length 908 mm, caliber 19 mm. Total length 1838 mm, barrel length 1255 mm, caliber 26.5 mm.

- p. 69:
  - In the early 1970s, Alan R Williams of the University of Manchester Institute of Science and Technology test-fired three different replica handgonnes. All had a bore of ¾ inch (19 mm) and varying lengths of 5 inches (127 mm), 10 inches (254 mm), and 15 inches (381 mm) with the 5-inch handgonne supposedly common in the 14th century, the 10-inch in the early 15th century, and the 15-inch in the late 15th century. Muzzle velocity for lead balls ranged from 195.1 m/s for the short barrel, 152.4 m/s for the medium, and 563.9 m/s for the long. The short barrel had a muzzle velocity of 179.8 m/s, the medium 158.5 m/s, and the long 469.4 m/s for lead balls. Williams found that the handgonnes were generally accurate at 9.1 m, but their accuracy became uncertain at longer ranges.
  - p. 75: In 1998, Thom Richardson of the Royal Armouries and his team conducted ballistic tests on a variety of weapons, measuring the velocity of shot from everything from slings to arquebuses. The least effective longbow, with a 72-lb draw at 28 inches (711 mm), drawn to 27 inches (686 mm), and firing swallow tail arrows, had an average velocity of 37.4 m/s.
  - The most effective longbow, a replica of a specimen found in the *Mary Rose* with a 90-lb draw at 28 inches, drawn to 27 inches, and firing an arrow also reconstructed from a *Mary Rose* find, had an average velocity of 44.5 m/s.
  - The best crossbow tested, a replica of a 15th-century crossbow with a steel bow and a draw weight of 440 lb, spanned by a windlass, had an average velocity of 44.7 m/s.
  - Tested a replica 15th-century hackbut firing a 15.75-mm lead ball and using a 50-gr charge of modern gunpowder. This had the average velocity of 180.5 m/s. Replicas of early 16th-century matchlock arquebuses proved to be even better, with the best having an average velocity of 521.2 m/s, firing a 12.7-mm lead ball with a 90-gr charge of modern black powder.
- p. 76: Re-enactors using replica handgonnes have shown that these disadvantages may not have been as great as generally assumed. Hitting

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person-sized targets at 10 m or even 45 m with a pre-matchlock handgonne is not impossible, although it does require considerable practice.

Note 51a

Assuming a bow efficiency of 0.85, for "the least effective longbow" in Note 51, p. 75, I calculate the arrow energy from the draw weight and draw length, and then use the cited velocity to arrive to an arrow mass of 130 g.

Note 51b

Using data in Note 51, p. 75, regarding "the most effective longbow" and assuming the bow efficiency of 0.85, I calculate the arrow energy from the draw-weight and draw-length, and then use the cited velocity to arrive to an arrow mass of 115 g.

Note 51c

I use the velocity of a crossbow bolt mentioned in Note 51, p. 75, and the weight of the bolt of 60 g. Assuming a 5-inch draw-length, I calculate the efficiency of this crossbow as 48%.

Note 52

From Williams (2003):

- p. 55: A knight's rigid breastplate enabled the use of a lance-rest, which transmits a part of the KE of the horse to the lance.
- p. 877: Medieval swords were 1 to 1.5 kg.
- p. 916: Thickness of armor was 1.5 to 3 mm in 1450–1550, but in 1550–1650 was 1.5 to 6 mm.
- p. 918: Swords, spears, and axes deliver 60–130 J.
- pp. 918–919: A longbow with a 50-lb draw produced 20 ft × lb (170 J) A longbow with a 75-lb draw produced 212 J. A yew longbow of 80-lb draw, 50-g arrow: velocity 53 m/s, 70 J. A yew longbow of 80-lb draw, 90-g arrow: velocity 43 m/s, 83 J. A modern crossbow of 90-lb draw, 100-g bolt: velocity 62 m/s, 192 J.
- pp. 919–920: Crossbow draw of 1200 lb, 80 g bolt: velocity 200 J.
- p. 920: 14th-century handgun 200 mm long and 23 mm bore with a 50-g lead ball: muzzle velocity at least 100 m/s, muzzle energy 250 J. A wheel-lock musket, 50-g bullet: 190 m/s, 900 J. A bow of 30-kg draw, 50-g arrow: 41 m/s, 42 J. A crossbow of 330-kg draw, 100-g bolt: 43 m/s, 92 J.

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- p. 921: Hussite guns of the early 15th century: 250 m/s, muzzle energy 1000–1200 J. A harquebus of the late 15th century: 1300 J; with corned powder 2000 J. A musket of the early 16th century: 2000 J; with corned powder 3000 J.
- p. 922: Tables of data on velocity, muzzle energies, and so on.

Note 53

Data on single-shot breech loaders of the 1870–1880s are given in https://en.wikipedia.org/wiki/Werndl%E2%80%93 holub_rifle.

Note 54

"Typical of smoothbore muskets, the M1795 had an effective range of about 50 yd (46 m) to 75 yd (69 m)." From https://en.wikipedia.org/wiki/Model_1795_Musket.

Note 55

"Yet the Minié-type rifled muskets were much more accurate than smoothbore muskets. The loose-fitting ball in a smoothbore musket was accurate to ranges of 50 to 75 yd (46 to 69 m) or less. Rifled muskets increased the effective range to about 200 to 300 yd (180 to 270 m)". From https://en.wikipedia.org/wiki/Rifled_musket.

Note 57

From Rose (2009):

In US tests of early 1800s, at 100 yd, rifles and smoothbores ranged 25–36% hits at a target. Cited in https://en.wikipedia.org/wiki/M1819_Hall_rifle.

Note 59

On the effective range of firearms during the American Revolution (Raphael 2013):

"Not until the British 'came within 10 or 12 rods,' " wrote the Committee of Safety, "did the Americans commence their first volley. On the second charge, they waited till the enemy was '5 or 6 rods' away, still about 30 yd (one rod is 16.5 ft, so '10 or 12 rods' translates to 165 to 198 ft, or 55 to 66 yd, and '5 or 6 rods' to 82.5 to 99 ft, or 27.5 to 33 yd)". (Raphael cites from Frothingham [1873].)

Note 60

For this weapon, I used data in the corresponding Wikipedia article. In most cases, these data were at least partly checked against Ezell (1983), Lewis (1956), and Blair (1983).

Note 61

From Parker (1996):

- p. 17: In 1490 the Venetian Republic decided to replace crossbows with firearms. Other states soon followed.
- p. 17: The arquebus of the early 16th century took several minutes to reload and was accurate only up to 100 m.
- p. 17: Crossbowmen largely disappeared by mid-16th century. England abandoned longbow in 1560s.
- p. 35: In the battle of Culloden, improved fire control meant that Hanoverian musketeers fired only when the clansmen were 12 m away.

Note 62

From Kerr (2015):

- p. 16: The French program of research and development of small arms with their smoothbore musket of 1800. This test consisted of firing at a target 1.9 m high by 32 m wide, with 100 rounds. Table 1 shows number of hits as a function of range. Cited from Lewis (1956, p. 91). [*Data compiler's note: Even with very large target, hits at 78.5 yd were 67%; if scaled proportionately to human-sized target, it will be far below 50%.*]
- p. 16: Model 1855 marked the end of US manufactured smoothbores.
- p. 19: Twenty men fired five rounds in volley and five in file at a target 6 ft high by 20 ft wide. Using rifles as the standard weapon, this test proved the superior ballistics of the Minie ball. Both had similar effectiveness to 200 yd, but the added velocity and stabilization make the Minie ball results much better at 400 yd (4.5% vs. 52.5%). The test results are shown in Table 2 in Lewis (1956, p. 103).
- p. 22: In ideal conditions then, a rifle using percussion caps could fire two rounds per minute.
- p. 24: The French compared their smoothbore musket against a tige rifle, which used a spherical bullet. The Minie ball was superior to the tige bullet, so these results are a comparison of smoothbore versus rifled bore. In the test, one marksmen fired 60 rounds at each range. The percentage of hits at ranges indicated are in Table 5 in Lewis (1956, p. 105).
- p. 25: The United States War Department conducted a rifle/musket comparison in February 1860.

- p. 25: A study of the accuracy, range, and rate of fire of the 0.58-cal. rifle musket against several other weapons, including 1843 Model 0.69-cal. smoothbores. Figure 3 in Fuller (1958, p. 53–148) is a summary of those results for the 0.58-cal. rifle and the 0.69-cal. smoothbore fired at a 10-ft-sq panel. Figure 4 in Fuller (1958, p. 53–148) shows a similar test fired at a 6-ft-sq panel.
- p. 52: In the Civil War, a Soldier carried, on the average, about 60 rounds. At a maximum rate of 2 rounds per minute they could last about 30 min before running out of ammunition. Typically, this rate was not sustained. Most battles lasted for 2 to 4 h before requiring resupply.
- p. 60: As Soldiers on both sides fought to maximize their protection while shooting at enemy Soldiers in the open, the engagement distance increased dramatically. The range of the smoothbore musket was often debated, some saying it was worthless beyond 50 yd, but very few believed in its effect above 150 yd. The units at Antietam often became decisively engaged at twice that distance.
- p. 62: The Confederate experience also involves engagements above 300 yd.

Note 65

From Duffy (1988):

- p. 168: The load of foot soldier is remarkably consistent over centuries, about 60 lb; of which in the 18th century 10–11 lb was musket and bayonet, and 10 lb for 60 cartridges.
- p. 207: 18th-century Prussian tests against a target 6 ft high and 100 ft wide; at 100 paces (60 m): 92 hits out of 200; at 120 m: 64 hits.
- p. 208: Men rarely bothered to seat the muskets butt firmly against shoulder; added to inaccuracy. Real execution of hits started only at 50 yd; beyond that hits were few. At 100 yd, no hits; at 40 yd, you see a good number.
- p. 215: Fifty paces (30 m) is when musket fire became really effective.

Note 66 – Baker Rifle

See http://therifleshoppe.com/catalog_pages/english_arms/baker_rifles.htm and https://warfarehistorynetwork.com/daily/military-history/the-accurate-and-deadly-baker-rifle/.

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Test show that both the Brown Bess and Baker had a velocity of about 1050 fps: see https://m.youtube.com/watch?v=uxzjDN2-VoU.

A 0.625 ball or 0.615—unclear. Year—1800. Range—at least 270 m based on reported tests. Rate—1.5 per min.

Note 67 – Brunswick Rifle

A 0.704 ball. Year—1836; 3 per min but "difficult to load". At 300 yd, "more accurate than Baker".

https://www.google.com/amp/s/hoveysknivesofchina.com/2010/11/13/getting-the-75-caliber-brunswick-rifle-and-a-50-caliber-traditions-magnum-hawken-ready-for-idaho-elk/amp/.

Chronograph shows the Brunswick rifle gave velocities of between 1121 and 1131 fps, for a 471-gr belted ball.

Note 68 -- French Minie Rifle

See https://fr.m.wikipedia.org/wiki/Fusil_Minié.

Mass—32.4 g. Year—1849. Range—550 m [*Data compiler's note: Range or effective range?*]. Rate—2–3 per min, according to http://guns.wikia.com/wiki/Minié_rifle, it had muzzle velocity—900 fps.

Note 69

From Haughton (1868):

Describes early 1860s experiments with two rifles and their bullets.

Two-grooved was a Brunswick rifle (stated in the paper). "Belted" bullet mass = 482 gr = 0.0312 kg. Muzzle velocity reported in the paper—1022 fps.

Minie "Regulation" Rifle was probably an Enfield 1853 rifle. Mass = 697 gr = 0.0451 kg. Velocity reported in the paper—909 fps.

Note 70

This source shows experiment where an Eli Whitney 1812 musket [*Data compiler's note: Assume it was a modification of the Springfield 1795?*] muzzle velocity was about 1000 fps: https://m.youtube.com/watch?v=pk5p3tDxhrs.

Note 71

Musket ball sizes:

- Source: https://classroom.synonym.com/identify-revolutionary-war-musket-balls-7633630.html.
- The British Brown Bess musket had a 0.75-inch bore but took a 0.693-inch-diameter ball. Charleville-style French muskets, which were supplied to the Continental Army, had a 0.69-inch bore but took a 0.63-inch ball.
- [*Data compiler's note: Based on Note 48, which claims a muzzle velocity =1500 fps for Brown Bess, I also assume the same velocity for Charleville.*]

Note 72

From Hughes (1975):

- p. 10: Independent shooter could fire 5 rounds (musket), in volleys—2–3 per min.
- p. 10: Brown Bess was 0.76 inches in caliber; bullet 0.71 inch in diameter; windage (gap) was 1/20 inch.
- p. 11: Rifles invented in middle of the 16th century. the Baker rifle bullet was 350 gr.
- p. 26: Musket: max rate of fire is 2–3 shots a minute; French fusil in the 18th–19th century—320 m/s; good marksman just possible to hit a person at 100 yd. Brown Bess might hit at 80 yd but beyond that is pure luck.
- p. 27: Musket: under battle conditions, trained Soldiers, fire at a target 1.75 m by 3 m—60% hits; a target-like line of cavalry—ordinary Soldiers get 40% hits at 100 yd.
- p. 29: Musket: at 100 yd 75% hits on target 6 ft by 20 ft. Baker rifle: deadly up to 200 yd; dangerous at 200–300 yd in hands of a marksman.
- p. 85: Musket highly effective at 60 yd or less.
- p. 119: "The definition of maximum effective range of the musket is controversial".

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Note 73

From Nafziger (1996):

- p. 31: Times per rifle shot as compared to musket in 1810 experiment was 5 to 1 or 5 to 2.
- p. 38, chart 3: A 50% probability of hit for muskets of about 1800, at 100 to 50 yd or less under realistic conditions. And this against a company-sized target.

Note 74

From Hall (1997):

- pp. 16–17: Dates in crossbow development: in the West, emerged in the 10th century; played important role in the First Crusade (1069–1099)—able to pierce mail armor at close range; more powerful than recurved bow, which could not penetrate even a quilted coat; very extensive use in the 13th century; steel crossbows in the 15th century.
- p. 18: Crossbow of the 15th century was 1 shot per minute. Not effective even at 80 m. European bows were almost all self-bows, meaning not recurved.
- p. 19: Longbows could only harass beyond 150 m. Had enough KE to pierce low-grade armor at 60–120 m.
- p. 95: Small arms dating 1399–1430 had short bored portions between 11.4 and 16 calibers. Nuremberg of 1462 stipulated five calibers with bullets of 75, 35, 25, 21.25, and 12.5 g.
- p. 97: With certain powders, the arquebus would only throw a ball 15 ft; 15th-century gunsmiths optimized the arquebus at 70 calibers, about 40 inches long.
- p. 129: In late 1400s Spain, the arquebus was used along with the crossbow, probably for similar tactical roles and comparable ranges.
- p. 136: Muskets of the mid 1700s showed a much higher velocity, on the order of 450 mps versus 300 mps for mid 1800s. Because powder charge was 50% of ball weight versus 11%. [*Data compiler's note: Perhaps because body armor was no longer used.*]
- p. 138: Range of lethality of early modern weapons was less than 100–120 m. In the 16th–17th centuries, when armor was used, down to 25–30 m.

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- p. 140: Pistols were assumed accurate at 30 m. [*Data compiler's note: Somewhat comparable to handgonnes in terms of D/L ratio of the barrels.*]
- p. 169: The arquebus of 1500 could injure an armored knight only at 30–40 m.
- pp. 176–177: The heavy Spanish musket appeared about 1521. A heavy version of the arquebus up to 9 kg and bullets of 50–70 g. Lasted until the early 1600s. Then the musket became same as the earlier arquebus: under 5 kg and bullets of 15–20 g. The reason for the heavy musket was armor. Even it was limited in lethality to under 100 m.
- p. 187: In the battle of Ceresole 1544, arquebuses were ordered to fire at 5 m. They were protected by pike.
- p. 193: Reiters pistols were effective at 5–10 m. They were like an arquebus with a short barrel.
- p. 212: The original arquebus was intended for firing from a city wall against attackers [*Data compiler's note: Perhaps implying a short range comparable to wall height or less*] or in defense of a field fortification at ranges comparable to a pike.
- p. 213: Pistols allowed shots only at a few meters away.

Note 75

See http://albrechts.se/handgonnes-and-cannons-of-the-middle-ages/

Mentions 25 m as the range of handgonnes.

Note 76

From Strickland and Hardy (2005):

- p. 18: Arrows of 100 g or more require bows with a 143–165 lb pull.
- p. 26: Arrows of 58–75 and 31–42 g could be shot from a bow with a 160–175 lb pull...or 100-lb pull with reduced range. By the mid-14th century, arrow weight and bow pull took a leap. By the time of Agincourt in 1415, to defeat full plate armor, arrows went up to 113 g.
- p. 30: Bows of 135–160 lb pull, like those found on *Mary Rose*, needed arrows of 100–120 g to be fully effective.
- p. 31: Tested longbow initial velocity of 52 mps, 150-lb pull, arrow 108 g.

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- p. 31: Ferguson rifle was accurate at 183 m; an expert could do 4 shots a minute on average.
- p. 39: 10th-century bow "Ballinderry 1" compares to average *Mary Rose* as follows: length 185 cm vs. 188; thickness 2.86 vs. 3.15; width 3.80 vs. 3.42. [*Data compiler's note: Using cantilever beam formula, these two bows are essentially identical in force for a given deflection.*]
- p. 48: The shortbow is a myth. At all times, certainly even at Hastings in 1066, these bows were essentially longbows.
- p. 98: Europeans encountered a Turkish composite bow shot by house archers in 1097.
- p. 99: Turkish bows had a pull between 60–100 lb. A bow of 40.5 lb shot a 578-gr arrow.
- p. 110: Composite bows were used in Byzantine, Italy, and Sicily, since before the 10th century.
- p. 120: Crossbow of the 13th century: 330 lb. Up to 460 lb.
- p. 121: Handheld crossbows shot quarrels of 42–152 g, heavier than ordinary arrows. Early hand-spanned crossbows had a 150-lb pull, perhaps in 1216 or earlier.
- p. 122: The cranequin appeared in 1370 or earlier. Windlass described in 1297. The 15th–16th century crossbows included examples of a 1090–1200 lb pull.
- p. 398: A modern test of a 16th-century arquebus showed a 340-mps velocity and 1150-J ME. Musket (after 1550) showed 482 mps, 4400 J.
- p. 409 (table 2): With a 150-lb pull longbow, a replica of those from *Mary Rose* (data obtained in 2002): arrow of 53.6 g yielded an average velocity 66 mps, 95.9 g—52.5 mps, 74.4 g—57.5 mps, 57.8 g—62.5 mps, and 86.6 g—53.5 mps.

Note 76a

I interpret the comments of Note 76, pp. 26, 30, and 31, to construct two date points. One bow is assumed in the year 1350 to have a 150-lb pull, an arrow of 108 g, and a velocity of 52 mps. Another in the year 1100 to have a pull of 100 lb with an arrow of 42 g. Assuming the same bow efficiency and the same draw length, the second bow yields a velocity of 68.7 mps.

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Note 76b

Based on Note 76 (p. 120), I estimate the energy of the bolt with a 460-lb pull and 5-inch draw length, with a 35% efficiency; the bolt was assumed to be 60 g.

Note 76d

Based on Note 76 (p. 26), I assume that lighter arrows of tests on p. 409 represent the 11th and 12th centuries, while the heavier arrow represents the 13th and 14th centuries. Thus, I assign the tests of an arrow of 53.6 g to mid-11th century, 57.8 g—to 12th century, 74.4 g—13th century; 95.9 g, and 86.6 g—14th century.

Note 77

1780 Jaeger rifle made in Aachen; data from https://youtu.be/VabA4u-8f3w.

A 292-gr ball with 100 gr of powder, 1545-fps velocity.

Note 78

Boit (1991) argues that during the 12th century, Turkish archers developed the "smooth" form of their composite bow as a way of increasing the effective range of the bow and minimizing the need to enter the range of European crossbows. This occurred possibly soon after the Turkish light-armored archers encountered the Crusaders' crossbows during the First Crusade.

Note 79

From Fadala (1995):

This publication presents test data for replicas of several historical muzzleloaders. Muzzle velocities obtained with powder loads that the author called "optimum" are cited as follows:

- p. 171: Hawken rifle (1823), caliber 53, 211-gr ball, 1873 fps
- p. 180: Hawken rifle, caliber 50, 177 gr, 1793 fps
- p. 181: Kentucky rifle, caliber 45, 128 gr, 1856 fps
- p. 187: Hawken rifle, caliber 50, 177 gr, 1939 fps
- p. 228: 1853 Enfield, caliber 58, 505 gr, 1195 fps
- p. 236: 1841 Mississippi rifle, 530 gr, 1034 fps
- p. 241: Whitworth rifle [1854], 490 gr, 1306 fps
- p. 242: Pennsylvania rifle, caliber 32, 45 gr, 1747 fps

Note 79a

The origins of the American long rifle, aka the Pennsylvania rifle, aka the Kentucky rifle, date to about 1725 (Rose 2008, p. 17).

Note 80

I define the efficiency of a bow or crossbow as the ME of the arrow/bolt divided by the potential energy introduced into the bow by straining it. The latter, for medieval bows and crossbows, I estimate as half of the product of the maximum draw-weight and draw-length. Medieval bow efficiency is on the order of 0.75–0.92 (e.g., see the source in Note 5), and I typically assume 0.85. Crossbow efficiency is less well understood or documented. Using several sources for test data, I calculated crossbow efficiencies ranging from 0.15 to 0.60, but more commonly between 0.30 and 0.45. When I had to assume the efficiency of a crossbow, I assumed 0.35.

Note 81

According to Wayland (n.d.), the Japanese tanegashima matchlock firearm was built in Japan since 1543; a typical example used a 578-gr ball with a muzzle velocity of at least 1200 fps.

Note 82

A test of a crossbow with a 1000-lb draw-weight was reported on https://m. youtube.com/watch?v=kHnZo6ELEV0.

The measured bolt velocity was 157 fps; 96-g bolt; spanned with a windlass. Efficiency—0.389. The windlass is probably characteristic of late 13th or mid-14th centuries (Loades 2018, p. 32). I assume 1350.

Note 83

Miller (2010) summarizes literature on the muzzle velocities of muskets, with an about 16.94–19 mm diameter ball. The 17th-century muskets had muzzle velocities on the order of 400–430 m/s. In the 18th–19th centuries, muskets' muzzle velocities were closer to 450–500 m/s.

Note 84

Hogg (1985) brings data on rifle ammunition, including muzzle velocity (MV) and ME:

Rifle ammunition:

- G11 assault rifle, 4.7 mm caseless, MV 930 mps, ME 1470 J
- AKS-74, Soviet 5.45 mm, MV 900 mps, ME 1391 J

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- Armalite and M-16; NATO 5.56 mm, MV 922 mps, ME 1680 J; Ball M193 is 3.56 g, 975 mps, 1692 J
- Arisaka rifle, 1897, 6.5 mm, MV 762 mps, ME 2613 J
- 6.5-mm Mannlicher-Carcano, MV 700 mps, ME 2572 J
- 7.5-mm MAS, 9.07 g, MV 793 mps
- 7.62-mm Mosin-Nagant, MV 818 mps, ME 4008 J
- 7.62-mm Kalashnikov, MV 710 mps, ME 2010 J
- Lee-Metford, Lee-Enfield, 0.303, since 1889, MV 731 mps, ME 3011 J
- MP43, 7.92-mm Sturmgewehr, MV 700 mps, ME 1984 J
- 7.92-mm Mauser, since 1888, MV 837 mps, ME 4040 J
- 8-mm Austrian Mannlicher, since 1888, MV 620 mps, ME 3038 J
- 8-mm Danish Krag-Jorgensen rifle of 1889, MV 770 mps, ME 3765 J
- 8-mm Lebel, since 1886, MV 732 mps, ME 3357 J

Heavy machine gun ammunition:

- 0.50 Browning, MV 854 mps, 16774 J
- 12.7-mm Soviet, for a Dyagterev DK machine gun; MV 840 mps, ME 15570 J
- 14.5-mm Soviet, for PTRS and PTRD antitank rifles, then for KPV heavy machine gun; MV 976 mps, ME 30215 J

5. Data Set of Ground-Mobile, Direct-Fire Weapon Systems (MFS)

The data in this section refer to what I call ground mobile (i.e., commonly maneuvering on the ground during a battle) weapon systems that achieve their effects on hostile targets via the KE of their projectiles, delivered at line of sight along a relatively flat trajectory. This excludes, for example, medieval artillery that remained generally static during a battle; heavy artillery that is not commonly used in a ground maneuver during an engagement; and indirect-fire artillery or use of explosive shells, and so on.

The first column of the data table (Table 2 in Section 5.1) describes the system. An infantryman with a weapon is a type of a ground-mobile, direct-fire system. Acronyms in this column are as follows: LAI refers to light armored infantry; LNI refers to light infantry without armor; and MAI refers to modern infantry that uses body armor. The data referring to infantry small arms' characteristics (muzzle velocity, projectile mass, effective range, and range of fire) are reused from the data set of Section 4. In the third column, each note number is preceded by the letters "MFS" to distinguish this set of notes from the notes in Section 4. Note numbers are not necessarily consecutive; there are gaps in the numbers.

Year of introduction, projectile mass, muzzle velocity, effective range, and rate of fire have been already discussed in Section 4.

Protection here is of a rather qualitative nature. It is taken as the ME (in joules) of a weapon that is considered in the literature as reasonably effective in defeating the system. For example, the protection of a Panzer IV of the 1943 version is considered in literature as reasonably adequate (although certainly not invulnerable) against the contemporary T-34. In other words, the Panzer IV "meets its match" in the T-34. Thus, I take the ME of the T-34 gun as roughly indicative of the level of protection of the Panzer IV. Needless to say, this is a very approximate and nearly qualitative rather than quantitative approach.

System mass includes everything that is directly required for that system to maneuver and operate tactically on the battlefield. In the case of an infantryman, it includes the mass of the person's body, the armor, and typical equipment, as well as the weight of the weapon(s) and ammunition. In the case of the cavalryman, the mass of the horse is included. In case of a towed cannon, the mass of the limber, ready ammunition, horses, and crew are included; caissons with additional ammunition are seen here as part of logistic support and are not included.

The motive power of the system is the power directly available to move the system on the battlefield. In the case of an infantryman, this is typically about 0.1 hp, the representative power of a human. For horse-towed artillery, this includes the power of the horses and the crew. For modern systems, it is the engine power of the platform or of the towing truck.

Crew is the number of personnel directly serving the system during the engagement. It ranges from 1 in the case of an infantry or cavalryman, to as many as 15 in the case of an artillery piece.

Offroad speed is rather approximate and characterizes the speed with which the system can maneuver on the broken terrain of a battlefield for a relatively prolonged time as opposed to a short sprint.

Further discussion and details are found in the notes in Section 5.2.

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5.1 Table of Data

Table 2 provides the data set for ground-mobile, direct-fire weapons.

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Table 2 Data set of ground-mobile, direct-fire weapon systems

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LAI w/ Byzantine bow (1)	45a	MFS011a, MFS023a	1100	0.0320	75	160	75	5	85	0.1	1	3
Cataphract w/ Byzantine bow	. . .	MFS010a	1100	0.0320	75	200	75	5	620	1.1	1	15
LAI w/ Byzantine bow (2)	45b	MFS011a, MFS023a	1100	0.0600	55	160	75	5	85	0.1	1	3
LAI w/ bow	46a	MFS011a, MFS023a	1100	0.0358	60	160	75	5	85	0.1	1	3
LAI w/ longbow	76, 76d	MFS011a, MFS023a	1101	0.0536	66	160	75	5	85	0.1	1	3
LAI w/ longbow	8, 76 (p. 48)	MFS011a, MFS023a	1101	0.1020	47	160	75	5	85	0.1	1	3
LAI w/ longbow	76a	MFS011a, MFS023a	1101	0.0420	69	160	75	5	85	0.1	1	3
LAI w/ longbow	76, 76d	MFS011a, MFS023a	1150	0.0578	63	160	75	5	85	0.1	1	3
LAI w/ Turkish warbow	5	MFS011a, MFS023a	1101	0.1002	40	160	75	5	85	0.1	1	3
Turkish archer w/ warbow	5	MFS011a, MFS023a	1101	0.1002	40	160	75	5	570	1.1	1	25
LAI w/ Turkish warbow	5	MFS011a, MFS023a	1125	0.0691	48	160	75	5	85	0.1	1	3
LAI w/ Turkish warbow	5	MFS011a, MFS023a	1150	0.0478	56	160	75	5	85	0.1	1	3
LAI w/ Turkish warbow	5	MFS011a, MFS023a	1175	0.0338	65	160	75	5	85	0.1	1	3
LAI w/ longbow	76, 76d	MFS011a, MFS023a	1250	0.0744	58	160	75	5	85	0.1	1	3

Table 2 Data set of ground-mobile direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LAI w/ longbow	51a	MFS011a, MFS023a	1250	0.1300	37	160	75	5	85	0.1	1	3
LAI w/ longbow	51b	MFS011a, MFS023a	1300	0.1150	45	160	75	5	85	0.1	1	3
LAI w/ yew longbow	52, p. 918-919	MFS011a, MFS023a	1300	0.0500	53	160	75	5	85	0.1	1	3
LAI w/ yew longbow	52, p. 918-919	MFS011a, MFS023a	1301	0.0900	43	160	75	5	85	0.1	1	3
LAI w/ longbow	76, 76d	MFS011a, MFS023a	1325	0.0866	54	160	75	5	85	0.1	1	3
LAI w/ longbow	76a	MFS011a, MFS023a	1351	0.1080	52	160	75	5	85	0.1	1	3
LAI w/ longbow	76, 76d	MFS011a, MFS023a	1375	0.0959	53	160	75	5	85	0.1	1	3
LAI w/ crossbow d-w 600 lb	3, 3a	MFS011a, MFS023a	1190	0.0600	45	160	75	1	85	0.1	1	3
LAI w/ crossbow	52, p. 920	MFS011a, MFS023a	1200	0.1000	43	160	75	2	85	0.1	1	3
LAI w/ crossbow	76b	MFS011a, MFS023a	1251	0.0600	39	160	75	2	85	0.1	1	3
LAI w/ crossbow	51c	MFS011a, MFS023a	1300	0.0600	45	160	75	2	85	0.1	1	3
LAI w/ crossbow d-w 750 lb	3, 3a	MFS011a, MFS023a	1351	0.1000	39	160	75	1	85	0.1	1	3
LAI w/ crossbow, 1000 lb	82	MFS011a, MFS023a	1351	0.0960	48	160	75	1	85	0.1	1	3

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LAI w/ crossbow, 740 lb	4	MFS011a, MFS023a	1370	0.0354	64	160	75	1	85	0.1	1	3
LAI w/ crossbow d-w 1500 lb	3, 3a	MFS011a, MFS023a	1399	0.1000	55	160	75	1	85	0.1	1	3
LAI w/ crossbow, 1090 lb	3, 3a	MFS011a, MFS023a	1450	0.1000	47	160	75	1	85	0.1	1	3
LAI w/ crossbow	52, p. 919-920	MFS011a, MFS023a	1400	0.0800	70	160	75	0.5	85	0.1	1	3
LAI w/ Loshult handgonne	51, p. 9	MFS011a, MFS023a	1350	0.1840	142	160	25	0.5	85	0.1	1	3
LAI w/ handgonne	51, p. 69	MFS011a, MFS023a	1350	0.0410	180	160	25	0.5	85	0.1	1	3
LAI w/ handgonne	52, p. 921-922	MFS011a, MFS023a	1351	0.0385	239	160	25	0.5	85	0.1	1	3
LAI w/ handgonne	26	MFS011a, MFS023a	1362	0.0500	200	160	25	0.5	85	0.1	1	3
LAI w/ handgonne	52, p. 921-922	MFS011a, MFS023a	1400	0.0400	255	160	25	0.5	85	0.1	1	3
LAI w/ handgonne	52, p. 921-922	MFS011a, MFS023a	1400	0.0390	343	160	25	0.5	85	0.1	1	3
LAI w/ Hussite gun	52, p. 921	MFS011a, MFS023a	1420	0.0352	250	160	25	0.5	85	0.1	1	3
LAI w/ arquebus	42	MFS011a, MFS023a	1455	0.0278	240	160	50	1	85	0.1	1	3
LAI w/ harquebus	51, p. 26-27	MFS011a, MFS023a	1470	0.0160	450	160	50	1	85	0.1	1	3

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LAI w/ handgonne	51, p. 69	MFS011a, MFS023a	1490	0.0410	469	160	25	1	85	0.1	1	3
LAI w/ matchlock harquebus	51, p. 75	MFS011a, MFS023a	1520	0.0122	521	160	50	1	85	0.1	1	3
LAI w/ tanegashima	81	MFS011a, MFS023a	1543	0.0374	366	160	50	1	85	0.1	1	3
LAI w/ arquebus	76, p. 398	MFS011a, MFS023a	1550	0.0200	340	160	50	1	85	0.1	1	3
LAI w/ musket	76, p. 398	MFS011a, MFS023a	1550	0.0380	482	160	75	1	85	0.1	1	3
Knight, 16 cent., w/ pistol	. . .	MFS002, MFS039, MFS043, MFS057	1550	0.0097	385	300	10	5	620	1.1	1	15
LAI w/ heavy musket, rifled G284	47	MFS011a, MFS023a, 125	1571	0.0383	482	160	75	1	85	0.1	2	3
Reiter w/ pistol, sword	. . .	MFS002, MFS039, MFS043, MFS047, MFS057	1575	0.0097	385	250	10	5	600	1.1	1	15
LAI w/ heavy musket, rifled G358	47	MFS011a, MFS023a, 125	1580	0.0491	533	160	75	1	85	0.1	2	3
LAI w/ wheellock RG117	47	MFS011a, MFS023a	1593	0.0108	427	160	75	1	85	0.1	1	3

Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LAI w/ wheellock RG33	47	MFS011a, MFS023a	1595	0.0300	456	160	75	1	85	0.1	1	3
LAI w/ matchlock LG1514	47	MFS011a, MFS023a	1620	0.0174	449	160	75	2	85	0.1	1	3
Harquebusier w/ harquebus, sword	. . .	MFS048	1620	0.0250	200	160	10	30	600	1.1	1	15
LAI w/ wheellock RG272 rifled	47	MFS011a, MFS023a	1625	0.0321	392	160	75	2	85	0.1	1	3
LAI w/ musket	46, p. 70-71	MFS011a, MFS023a	1650	0.0410	306	160	75	2	85	0.1	1	3
LNI w/ flintlock STG1318	47	MFS011a, MFS023a	1686	0.0309	494	80	75	2	75	0.1	1	4
LNI w/ musket	12	MFS011a, MFS023a	1700	0.0198	550	80	75	2	75	0.1	1	4
LNI w/ flintlock musket STG1287	47	MFS011a, MFS023a	1700	0.0275	474	80	75	2	75	0.1	1	4
LNI w/ flintlock STG1316	47	MFS011a, MFS023a	1701	0.0321	451	80	75	2	75	0.1	1	4
LNI w/ flintlock STG1317	47	MFS011a, MFS023a	1701	0.0343	467	80	75	2	75	0.1	1	4
LNI w/ flintlock E28	47	MFS011a, MFS023a	1715	0.0299	543	80	75	2	75	0.1	1	4
LNI w/ Charleville	25, 71, 72	MFS011a, MFS023a	1717	0.0243	450	80	75	3	75	0.1	1	4
LNI w/ Brown Bess	16, 14, 48, 71, 72	MFS011a, MFS023a	1722	0.0329	450	80	75	3	75	0.1	1	4
LNI w/ Brown Bess	48, 71, 72	MFS011a, MFS023a	1722	0.0321	457	80	75	3	75	0.1	1	4

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LNI w/ long rifle - 1	19	MFS011a, MFS023a	1725	0.0107	366	80	200	2	75	0.1	1	4
LNI w/ long rifle - 2	19	MFS011a, MFS023a	1725	0.0062	488	80	200	2	75	0.1	1	4
LNI w/ Kentucky rifle	79, p. 181	MFS011a, MFS023a	1725	0.0083	566	80	200	2	75	0.1	1	4
LNI w/ Pennsylvania rifle	79, p. 242	MFS011a, MFS023a	1725	0.0029	533	80	200	2	75	0.1	1	4
LNI w/ flintlock musket STG1288	47	MFS011a, MFS023a	1775	0.0260	455	80	75	3	75	0.1	1	4
LNI w/ Jaeger rifle	77	MFS011a, MFS023a	1780	0.0189	471	80	200	2	75	0.1	1	4
LNI w/ Springfield M1795	60, 70	MFS011a, MFS023a	1795	0.0298	370	80	75	3	75	0.1	1	4
LNI w/ Baker rifle	66, 72	MFS011a, MFS023a	1800	0.0226	315	80	200	1.5	75	0.1	1	4
LNI w/ M1819 Hall rifle	60	MFS011a, MFS023a	1811	0.0140	330	80	200	8	75	0.1	1	4
LNI w/ Hawken rifle, cal. 53	79, p. 171	MFS011a, MFS023a	1823	0.0137	571	80	200	2	75	0.1	1	4
LNI w/ Hawken rifle, cal. 50	79, p. 180, p. 187	MFS011a, MFS023a	1823	0.0115	569	80	200	2	75	0.1	1	4
LNI w/ Dreyse needle gun	60	MFS011a, MFS023a	1836	0.0250	305	80	200	6	75	0.1	1	4
LNI w/ Brunswick rifle	60, 67, 69	MFS011a, MFS023a	1836	0.0312	312	80	200	2	75	0.1	1	4

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LNI w/ Mississippi rifle M1841	60	MFS011a, MFS023a	1841	0.0324	360	80	200	2	75	0.1	1	4
LNI w/ 1841 Mississippi rifle	79, p. 236	MFS011a, MFS023a	1841	0.0343	315	80	200	2	75	0.1	1	4
LNI w/ Sharps rifle	60	MFS011a, MFS023a	1848	0.0307	370	80	200	10	75	0.1	1	4
LNI w/ Fusil Minie	60, 68	MFS011a, MFS023a	1849	0.0324	270	80	200	3	75	0.1	1	4
LNI w/ Enfield 1853 rifled musket	60	MFS011a, MFS023a	1853	0.0324	270	80	270	3	75	0.1	1	4
LNI w/ Enfield 1853 rifled musket	69	MFS011a, MFS023a	1853	0.0451	277	80	270	3	75	0.1	1	4
LNI w/ Enfield 1853 rifle	79, p. 228	MFS011a, MFS023a	1853	0.0327	364	80	270	3	75	0.1	1	4
LNI w/ Whitworth rifle	79, 60	MFS011a, MFS023a	1854	0.0317	398	80	270	3	75	0.1	1	4
LNI w/ Chassepot	60	MFS011a, MFS023a	1858	0.0250	410	80	270	8	75	0.1	1	4
LNI w/ Springfield 1861	17	MFS011a, MFS023a	1861	0.0189	390	80	270	3	75	0.1	1	4
Cavalryman w/ Spencer carbine	60	MFS011a, MFS023a	1863	0.0230	370	80	270	20	590	1.1	1	25
LNI w/ Winchester	21	MFS011a, MFS023a	1866	0.0131	343	80	270	20	75	0.1	1	4
LNI w/ Werndl-Holub	53	MFS011a, MFS023a	1867	0.0240	439	80	270	7	75	0.1	1	4

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LNI w/ Vetterli	60	MFS011a, MFS023a	1867	0.0220	428	80	270	7	75	0.1	1	4
LNI w/ Berdan	23	MFS011a, MFS023a	1870	0.0198	437	80	270	7	75	0.1	1	4
LNI w/ Martini-Henri	2, 53	MFS011a, MFS023a	1871	0.0310	397	80	370	12	75	0.1	1	4
LNI w/ Mauser 1871	53	MFS011a, MFS023a	1871	0.0250	440	80	370	12	75	0.1	1	4
LNI w/ Springfield 1873	53	MFS011a, MFS023a	1873	0.0325	410	80	270	15	75	0.1	1	4
LNI w/ Gras rifle	22	MFS011a, MFS023a	1874	0.0249	455	80	250	7	75	0.1	1	4
LNI w/ Lebel rifle	60	MFS011a, MFS023a	1886	0.0150	610	80	400	21	75	0.1	1	4
LNI w/ Austrian Mannlicher	2	MFS011a, MFS023a	1886	0.0158	621	80	500	20	75	0.1	1	4
LNI w/ Lee-Metford	2, 60	MFS011a, MFS023a	1888	0.0116	564	80	500	20	75	0.1	1	4
LNI w/ Rubin	2	MFS011a, MFS023a	1889	0.0139	601	80	500	15	75	0.1	1	4
LNI w/ Belgian Mauser	2	MFS011a, MFS023a	1889	0.0142	620	80	500	15	75	0.1	1	4
LNI w/ Mosin-Nagant	60	MFS011a, MFS023a	1891	0.0097	865	80	500	15	75	0.1	1	4
LNI w/ Mosin-Nagant	2	MFS011a, MFS023a	1891	0.0138	588	80	500	15	75	0.1	1	4
LNI w/ Carcano	2	MFS011a, MFS023a	1891	0.0105	730	80	500	15	75	0.1	1	4

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LNI w/ Lee-Enfield	24	MFS011a, MFS023a	1895	0.0123	744	80	500	25	75	0.1	1	4
LNI w/ Mannlicher M1895	60	MFS011a, MFS023a	1895	0.0160	620	80	500	20	75	0.1	1	4
LNI w/ Arisaka Mauser	2	MFS011a, MFS023a	1887	0.0105	697	80	500	15	75	0.1	1	4
LNI w/ Mauser 98	60	MFS011a, MFS023a	1898	0.0146	639	80	500	15	75	0.1	1	4
LNI w/ Mauser w/ Spitzgeschoss	2	MFS011a, MFS023a	1905	0.0099	879	80	500	15	80	0.1	1	4
LNI w/ M1 Garand	60	MFS011a, MFS023a	1928	0.0110	853	80	500	40	80	0.1	1	4
LNI w/ SVT-40	60	MFS011a, MFS023a	1940	0.0097	835	80	500	25	80	0.1	1	4
LNI w/ Sturmgewehr 44	60	MFS011a, MFS023a	1942	0.0081	685	80	600	550	80	0.1	1	4
LNI w/ Gewehr 43	60	MFS011a, MFS023a	1943	0.0128	776	80	500	25	80	0.1	1	4
LNI w/ AK-47	29b	MFS011a, MFS023a	1947	0.0079	710	80	380	600	80	0.1	1	4
LNI w/ M-14	39	MFS011a, MFS023a	1949	0.0096	830	80	460	700	80	0.1	1	4
LNI w/ G3	60	MFS011a, MFS023a	1955	0.0110	800	80	500	550	80	0.1	1	4
LNI w/ M-16	29b	MFS011a, MFS023a	1957	0.0036	990	80	550	800	80	0.1	1	4

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
LNI w/ FN FAL	47	MFS011a, MFS023a	1958	0.0095	835	80	400	700	80	0.1	1	4
LNI w/ AK-74	60	MFS011a, MFS023a	1974	0.0034	880	80	500	600	80	0.1	1	4
LNI w/ SA 80	60	MFS011a, MFS023a	1975	0.0036	940	80	300	700	80	0.1	1	4
LNI w/ Steyr	47	MFS011a, MFS023a	1977	0.0036	990	80	300	700	80	0.1	1	4
LNI w/ FA MAS	35	MFS011a, MFS023a	1978	0.0036	993	80	400	1000	80	0.1	1	4
LNI w/ G36	60	MFS011a, MFS023a	1990	0.0036	920	1,000	500	750	80	0.1	1	4
MAI w/ M-4	40	MFS011a, MFS023a	1993	0.0041	900	1,000	500	700	105	0.1	1	3
MAI w/ FN SCAR-H	60	MFS011a, MFS023a	2004	0.0110	714	1,000	600	600	105	0.1	1	3
MAI w/ M-27	41	MFS011a, MFS023a	2008	0.0041	900	2,000	550	700	105	0.1	1	3
MAI w/ AK-12	60	MFS011a, MFS023a	2011	0.0036	900	2,000	600	700	105	0.1	1	3
MAI w/ AK-15	60	MFS011a, MFS023a	2011	0.0080	715	2,000	550	700	105	0.1	1	3
Mark IV	. . .	MFS058	1917	2.7000	411	4,000	1500	50	32000	105	8	5
FT tank	. . .	MFS060	1917	0.6700	600	16,000	1500	15	6500	39	2	5
A7V	. . .	MFS136	1917	2.7000	411	120,600	1500	25	33000	200	18	7
Vickers 6-ton tank	. . .	MFS061	1928	1.4700	560	30,000	1500	20	7300	98	3	17

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
T-26 tank	. . .	MFS062	1931	1.4300	760	4,000	1500	15	9600	90	3	16
Char B1 bis	. . .	MFS063	1934	1.7000	855	500,000	1000	15	28000	272	4	21
SOMUA S35	. . .	MFS064	1935	1.7000	855	270,000	1000	15	19200	190	3	16
KV-1 tank	. . .	MFS067	1939	6.5000	680	2,000,000	1500	10	45000	600	5	16
T-34 of 1941	. . .	MFS065	1940	6.5000	680	700,000	1500	10	29200	500	4	40
M4 Sherman	. . .	MFS071	1940	6.3200	619	1,500,000	2000	15	30300	350	5	20
Tiger I	. . .	MFS074	1941	10.2000	773	6,000,000	2000	15	57000	700	5	20
T-34/85	. . .	MFS066	1943	9.2000	792	2,000,000	2000	10	32000	500	5	20
Panzer IV	. . .	MFS068	1943	4.1000	990	2,000,000	2000	10	25000	296	5	16
IS-2 tank	. . .	MFS069	1943	25.0000	804	5,000,000	2000	5	46000	600	4	20
Sherman Firefly	. . .	MFS070	1943	3.5000	1185	2,000,000	2500	5	35300	425	4	20
Panther	. . .	MFS073	1943	7.2000	935	2,500,000	1600	10	44800	690	5	30
Tiger II	. . .	MFS075	1943	7.3000	1130	8,000,000	2500	15	68500	700	5	15
M26 Pershing	. . .	MFS072	1944	10.9000	1200	3,000,000	2000	8	41700	450	5	8
Centurion tank	. . .	MFS087	1946	5.8000	1478	5,000,000	2000	10	52000	650	4	17
T-54	. . .	MFS092	1949	15.6000	1000	8,000,000	2000	6	36000	500	4	35
M48 Patton	. . .	MFS090	1953	10.9000	1200	8,000,000	2000	32	45000	650	4	21
M60	. . .	MFS091	1960	6.1200	1490	8,000,000	2500	10	46000	750	4	16

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
T-64	· · ·	MFS093	1964	7.0500	1750	6,000,000	3000	8	38000	700	3	30
Chieftain tank	· · ·	MFS088	1965	7.6000	1370	7,800,000	3000	10	56000	750	4	30
Strv 103B (aka S-tank)	· · ·	MFS138	1971	7.6000	1370	7,800,000	3000	15	39700	490	3	30
T-72 tank	· · ·	MFS079	1972	3.9000	1785	6,000,000	3000	8	42500	780	3	45
T-80	· · ·	MFS094	1976	4.8500	1715	7,000,000	3000	8	46000	1250	3	48
M1 Abrams	· · ·	MFS080	1979	6.1200	1490	11,000,000	2500	6	54000	1500	4	40
Challenger 1	· · ·	MFS089	1982	4.0000	1740	11,000,000	3000	10	70000	1200	4	30
M1A1 Abrams	· · ·	MFS095	1986	4.8500	1700	11,000,000	4000	8	67600	1500	4	48
Challenger 2	· · ·	MFS139	1989	4.8500	1715	12,000,000	4000	10	75000	1200	4	40
Leopard 2A6M	· · ·	MFS137	2007	8.3500	1750	11,000,000	4000	8	62500	1479	4	48
T-14 Armata	· · ·	MFS114	2017	8.3500	1800	12,000,000	3000	10	48000	1500	3	45
T-14 Armata v2	· · ·	MFS114	2017	11.0000	2050	12,000,000	3000	10	48000	1500	3	45
Marder III	· · ·	MFS104	1942	4.0500	990	15,000	1800	14	10670	148	4	20
Sturmgeschütz III	· · ·	MFS105	1940	4.1000	990	1,500,000	1800	14	23900	296	4	20
Jagdpanzer IV	· · ·	MFS106	1943	4.7500	1130	1,500,000	3000	14	25800	296	4	20
M36 Tank Destroyer	· · ·	MFS107	1943	10.9000	810	1,500,000	2000	32	28600	450	5	21
SU-85	· · ·	MFS108	1943	9.2000	792	1,000,000	2500	10	29600	493	4	20

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
SU-100	. . .	MFS109	1944	15.6000	895	1,500,000	3000	5	31600	500	4	20
2S25 Sprut-SD	. . .	MFS112	2005	8.1000	1650	90,000	2000	7	18000	510	3	45
early-to-mid-1600s saker	. . .	MFS129	1625	4.0770	300	80	500	1	7140	9.2	12	5
early-to-mid-1600s minion	. . .	MFS128	1625	2.7180	300	80	450	1	5180	7	10	5
early-to-mid-1600s falcon	. . .	MFS127	1626	1.3590	300	80	400	1	3540	4.6	6	5
Saker in Battle of Cheriton	. . .	MFS145, MFS146	1644	2.4000	300	80	518	1	5700	7	10	5
Regimental Gun of mid-1600s	. . .	MFS126	1650	1.3590	300	80	200	2	1150	1.3	3	5
pre-Gribeauval, Austrian 12-pounder	. . .	MFS130	1740	5.4360	344	80	600	2	9350	11.5	15	5
pre-Gribeauval, Austrian 12-pounder v2	. . .	MFS130	1740	5.4360	437	80	600	2	9350	11.5	15	5
Canon de 8 Gribeauval	. . .	MFS096, MFS122	1765	3.8958	390	80	800	2	4731	5.3	13	5
Light 6-pdr	. . .	MFS144, MFS096	1776	2.7180	390	80	800	2	3555	5	10	5
Canon de 8 Gribeauval (HA)	. . .	MFS096a, MFS122	1790	3.8958	390	80	800	2	9911	15.5	15	15
Canon de 12 Gribeauval	. . .	MFS098	1765	5.8890	390	80	900	2	6323	7.5	15	5

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
Canon de 12 Gribeauval (HA)	⋯	MFS098a	1790	5.8890	390	80	900	2	11503	17.7	17	15
Canon de 4 Gribeauval	⋯	MFS099	1765	1.9560	390	80	700	2.5	3684	4.8	8	5
Canon de 4 Gribeauval (HA)	⋯	MFS099a	1790	1.9560	390	80	700	2.5	8864	15	10	15
British 1790 12-pdr	⋯	MFS132	1790	5.4360	440	80	900	2	6714	7.3	13	5
British 1790 12-pdr (HA)	⋯	MFS132a	1790	5.4360	440	80	900	2	11894	17.5	15	15
British 1805 9-pounder	⋯	MFS131	1805	4.0770	440	80	800	2	6200	7.2	12	5
British 1805 9-pounder (HA)	⋯	MFS131a	1805	4.0770	440	80	800	2	11380	17.4	14	15
French AnXI 12-pdr	⋯	MFS133	1808	5.4360	440	80	900	2	6337	7.3	13	5
French AnXI 12-pdr (HA)	⋯	MFS133a	1808	5.4360	440	80	900	2	11517	17.5	15	15
French AnXI 6-pdr	⋯	MFS134	1808	2.7180	440	80	700	2	4400	5	10	5
French AnXI 6-pdr (HA)	⋯	MFS134a	1808	2.7180	440	80	700	2	9580	15.2	12	15
Griffen 3-inch Ordnance Rifle	⋯	MFS135	1854	2.7180	460	80	1800	2	4236	4.8	8	5
Griffen 3-inch Ordnance Rifle (HA)	⋯	MFS135a	1854	2.7180	460	80	1800	2	9416	15	10	15

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Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
Napoleon 1857 gun	. . .	MFS077, MFS052, MFS144	1857	5.5719	457	80	1200	2	5550	6.8	8	5
Napoleon 1857 gun (HA)	. . .	MFS077a	1857	5.5719	457	80	1200	2	10730	17	8	15
Prussian C/61	. . .	MFS124	1857	6.7500	331	80	1500	3	5500	6.8	8	5
Prussian C/61 (HA)	. . .	MFS124a	1857	6.7500	331	80	1500	3	10680	17	10	15
RBL 12-pounder 8 cwt Armstrong gun	. . .	MFS100	1859	5.4400	378	80	3100	3	3610	4.8	8	5
RBL 12-pounder 8 cwt Armstrong gun (HA)	. . .	MFS100a	1859	5.4400	378	80	3100	3	8790	15	10	15
Parrott 10 pdr rifle	. . .	MFS078, MFS144	1860	10.0000	369	80	1700	2	5400	8.8	8	5
Parrott 10 pdr rifle (HA)	. . .	MFS078a	1860	10.0000	369	80	1700	2	10580	19	10	15
Canon de 75 modèle 1897	. . .	MFS101	1897	7.2500	500	3,000	1800	15	5444	6.6	6	10
British QF 13-pounder, horse artil.	. . .	MFS027, MFS144	1904	5.7000	511	3,000	1800	15	8428	12.9	6	15
3.7 cm Pak 36 antitank gun	. . .	MFS141	1933	0.6850	745	3,000	500	13	3567	38	5	15
47mm APX antitank gun	. . .	MFS140	1936	1.7000	855	3,000	550	17	4450	38	6	15

Table 2 Data set of ground-mobile, direct-fire weapon systems (continued)

System	Notes in Section 4	Notes in Section 5	Year of introduction (CE)	Projectile mass (kg)	Muzzle velocity (m/s)	Protection (J)	Effective range (m)	Rate of fire (rounds per min)	System mass (kg)	System motive power (hp)	Crew	Offroad speed (kph)
5 cm Pak 38 (L/60) antitank gun	. . .	MFS143	1940	2.2500	1130	3,000	1500	13	4170	38	5	15
6 pdr antitank towed gun	. . .	MFS082	1940	1.4200	1219	3,000	1500	15	4640	92	6	15
7.5 cm Pak 40 antitank gun	. . .	MFS076, MFS144	1941	4.0500	990	3,000	1800	14	9625	100	6	20
17 pdr antitank towed gun	. . .	MFS081	1942	3.4000	1200	3,000	1500	20	13120	147	6	20
17 pdr antitank towed gun, v.2	. . .	MFS081	1942	7.7000	950	3,000	1500	10	13120	147	5	20
8.8 cm Pak 43	. . .	MFS103	1943	10.4000	1000	3,000	2000	6	16850	133	6	20
100 mm antitank gun T-12	. . .	MFS110	1961	4.5500	1548	3,000	3000	10	15650	240	6	25
2A45M Sprut-B smoothbore 125 mm antitank towed gun	. . .	MFS111	1989	4.85	1715	3,000	2000	7	19600	240	7	25

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5.2. Notes on Sources

In the following, each note number is prepended with letters "MFS" to distinguish this set of notes from the notes in Section 4. Note numbers are not necessarily consecutive; there are gaps in the numbers.

MFS001: from Duffy (1988):

- p. 168: The load of a foot soldier is remarkably consistent over centuries, about 60 lb; of which in the 18th century, 10–11 lb was for the musket and bayonet and 10 lb for 60 cartridges.

MFS002: from Hall (1997):

- p. 140: Pistols were assumed accurate at 30 m.
- p. 193: Reiter's pistol was effective at 5–10 m. It was essentially a harquebus with a short barrel.

MFS004: from Strickland and Hardy (2005):

- p. 267: Early Middle Ages to 12th century—mail hauberk defends well against sword cuts, dagger thrusts, and Turkish composite bow arrows. Bodkin arrow could penetrate mail. At 15-ft range, an arrow from a 68-lb draw longbow could easily penetrate mail. Padded soft armor was usually added.
- p. 269: Soft armor required an additional 50–80 J to penetrate.
- p. 270: By 1260, additional small plates were common. Horses started to get barding of leather or even mail. By 1250, brigandine became common.
- p. 271: The first half of the 14th century saw rapid development of plate armor. A response to infantry with staff weapons and bows.
- p. 272: In 1346, the best armor defeated longbow. By 1400, a full suit of armor becomes common.
- p. 274: Full suit weighed about 60 lb. Still too heavy for a dismounted knight to walk any distance. By the early 15th century, the best hardened armor could defeat a longbow and crossbow.
- p. 275: In 1448, armor was expected to be proof against a windlass crossbow.
- p. 276: By the early 16th century, the longbow was ineffective against armor. But armor was ineffective against the harquebus.

- p. 277: An arrow of 70 g, 40.8 mps, at 15 ft can easily penetrated mail. A bolt of 33 g, 42.3 mps penetrated a helmet but not on rounder surfaces. A 3-mm thickness was typical for helmets, 2 mm for breastplate, and 1 mm for leg armor. An arrow or spear of 150 J could defeat poor-quality armor, but not high quality or at angle.
- p. 278: A 15th–16th century longbow of 150-lb pull, 108-g arrow has a KE of 146 J. A bodkin arrow of 75 J penetrated fully 1.9-mm wrought iron plate; with padding, it would take 125 J.

MFS008: From https://en.m.wikipedia.org/wiki/Cataphract:

A full set of cataphract armor could weigh 40 or 88 lb (not inclusive of the rider's body weight).

MFS010: From O'Rourke (2010):

pp. 10–16:

- Armored (mail or lamellar) cavalry with long lances
- Armored cavalry-archers (assume comparable to Turkish bows)
- Armored infantry with bows that were longer and more powerful than those of horse archers (assume comparable to the English longbow)
- p. 17: Interpreted by the compiler of the data:
  - Protection offered by
    - 1-mm plate: 55 J
    - 1.5-mm plate: 110 J
    - 2-mm plate: 175 J
    - Mail with leather coat: 120 J
- Assume that Byzantine cavalry or infantry were protected against 120 J plus 58 ft-lb (58 × 1.356 = 79 J) needed for incapacitation.
- Not clear how to account for unarmored horses. Although they could also have a degree of protection (e.g., leather armor).

MFS010a: I assume the year 1000. Armed with a Byzantine bow, using a 0.032-kg arrow. Protection is based on the Note MSF011a, 265 J. Horse and rider provide 1.1 hp. System mass: horse is 500 kg, horse armor is assumed 20 kg, rider's body 50 kg, rider's armor 30 kg (see Note MFS008), and other weapons and equipment 20 kg; total 620 kg.

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MFS011: For the 58 ft-lb rule, see https://history.amedd.army.mil/booksdocs/wwii/woundblstcs/chapter2.htm.

It is also mentioned and criticized as simplistic and lacking justification in Neades et al. (1984).

However, another source (Bellamy and Zajtchuk 1991) brings more modern approaches and mentions several corresponding data points ranging from 69 to 117 ft-lb, concluding that the historical value of 58 ft-lb for incapacitation may not be all that dubious.

MFS011a: For protection offered by armor, I make the following simplifying assumptions:

- LNI can be incapacitated by 80 J (see MFS011).
- LAI that wears something comparable to mail shirt over a soft padding, can be incapacitated by 160 J (80 J to penetrate the armor and 80 to incapacitate the body) (see Notes MFS004, MFS005, MFS010, and MFS011).
- Heavy armored infantry (HAI; plate armor and soft padding) can be incapacitated by 265 J (175 J to penetrate the plate and padding and 80 to incapacitate the body) (see Notes MFS004, MFS005, MFS010, and MFS011).
- MAI I consider protected against a weapon of an AK-47 type (ME about 2000 J) after the year 2000, and half of that in 1990–2000. See Note MFS051.

MFS012: Height of medieval soldiers was comparable to modern, see https://www.sciencedaily.com/releases/2004/09/040902090552.htm.

MFS013: This offers a more detailed study of English population:

http://www.ox.ac.uk/news/2017-04-18-highs-and-lows-englishman’s-average-height-over-2000-years-0#.

MFS014: I can assume weight by using body mass index (BMI). For normal range of BMI, see https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm.

BMI is a person’s weight in kilograms divided by their height in meters squared.

MFS015: per Orr (n.d.):

- The Byzantine heavy infantryman wore mail short or armor of 16 kg, plus spear, sword, and axe, for a total between 19.5 and 36.5 kg.

- During the English Civil War (1638–1651), an English pikeman wore corselet armor, helmet, and leg guards (total 11 kg), and carried a knapsack with food and clothing (additional 11.5–16.5 kg) and a 7-ft pike of 2 kg.
- British soldiers in American War of Independence carried 36.5 kg, including the musket, shot, and powder.
- French soldiers of the same period, 27.5 kg.
- During the Crimean War, the British load was 26–31 kg; the French was 33–36.5 kg.
- Union Army: 22.5 kg, including 60 rounds of ammunition and a tent shelter piece.
- Average weight of the American Soldier in the Civil War: 62 kg.
- In WW1, the average American Soldier was 64.5 kg, the load was 34%–50% of the body weight.
- In WW1, a British soldier was 60 kg and carried a load of 50%–57.5%.
- In WW2, the average American Soldier was 65.5 kg and carried a 42%–63% load.
- Vietnam: load of 27.5–32 kg; Marines: 36–45 kg.
- Americans in Afghanistan and Iraq: fighting load of 29 kg and approach march load of 43.5 kg.
- In general, from Roman times to today, the load was about 55% of body weight.
- For weight of a Soldier's body, I make the following simplifying assumption: prior to year 1900, 60 kg; after 1900, 65 kg.

MFS016: The power of a horse is about 1.0 hp, on a long term basis.

See https://energyeducation.ca/encyclopedia/Horsepower.

MFS017: The power of a human is about 0.1 hp indefinitely. See https://en.m.wikipedia.org/wiki/Horsepower.

MFS018: The strongest medieval chargers were 15–16 hands high. For long-distance riding, knights used palfrey horses. Palfreys had a more comfortable gait and were smaller and lighter.

See https://en.m.wikipedia.org/wiki/Destrier.

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MFS019: A horse of 15 hands seem to be typical for variety of uses.

See https://en.m.wikipedia.org/wiki/Horses_in_the_Middle_Ages.

MFS020: A height of 15 hands for the horse suggests a representative weight of 500 kg, unless it was a draught horse, which would more likely be 700 kg. See https://www.horsemart.co.uk/health/what-is-the-average-weight-of-a-horse-/659.

MFS023: Weight of armor: Even the heaviest tournament armor (for knights) weighed little more than 90 lb (41 kg) and field (war) armor 40 to 70 lb (18 to 32 kg); barding, or horse armor, rarely weighed more than 70 lb (32 kg).

See: https://en.m.wikipedia.org/wiki/Horses_in_the_Middle_Ages.

MFS023a: For mass of infantry with medieval armor, I make the following simplifying assumptions:

- LNI is 60–65 kg (see Note MFS015), the person plus 15 kg of weapons and equipment (see Notes MFS001, MFS012, MFS013, MFS014, and MFS015).
- LAI (wears something comparable to mail shirt or thin plate over a soft padding) is 60–65 kg, the person plus 25 kg of equipment (I assume a number between LNI and HAI).
- HAI (plate armor and soft padding) is 60–65 kg, the person plus 40 kg of equipment (see Notes MFS001, MFS012, MFS013, MFS014, and MFS015).
- MAI (wearing a combination of Kevlar or similar armor, with ceramic inserts, and a helmet) is 65 kg, a person plus 40 kg of armor and equipment (see Notes MFS015 and MFS050).
- For offroad speed, I make the following default assumptions, unless other information is offered in the literature:
    - All horse-mounted fighters, 25 kph; dismounted knight, 1 kph; LAI, 3 kph ; LNI, 4 kph ; MAI, 3 kph

MFS024: "Horse artillery units generally used lighter pieces (6-pounders), pulled by 6 horses; 9-pounders were pulled by 8 horses and heavier artillery pieces (12-pounders) needed a team of 12 horses...the ideal artillery horse was around 15–16 hands high (150–160 cm, 60–64 inches), strongly built, but able to move quickly". See https://en.m.wikipedia.org/wiki/Horse_artillery.

MFS027:

- System: QF 13-pounder; a British ordnance, similar to a French 75-mm field gun, but less successful, used with horse artillery units.
- Sources:
    - https://en.m.wikipedia.org/wiki/Ordnance_QF_13-pounder
    - Note MFS052
- Year: 1904
- Sysmass: 1528 kg, fully equipped gun (including carriage and limber). Add 12 horses (6 to tow and 6 for other members of the crew) and 9 gunners (assumed): total 8428 kg
- HP: 12 horses and 9 men; 12.9 hp
- Crew: 6 (per Note MFS052)
- Offroad speed: 25 kph (horse artillery was expected to gallop)
- Protection: shield
- Projmass: 5.7 kg
- Velocity: 511 m/s
- Rate of fire: 20 (per Note MFS052); however, I assume 15 as it is more consistent with better known French 75 mm, see Note MFS101.
- Effective range (Effrange): 5400 m is stated in literature; however, like in Note MFS101, I assume 1800.

MFS033: Detailed description of Polish hussars:

http://www.kismeta.com/diGrasse/HowHussarFought.htm.

They attacked at the canter speed about 40 kph (11.mps); lances were about 5.5 m and usually broke on impact. An assistant who did not normally charge and was armed with a firearm and would carry three replacement lances.

MFS036: Horses pulled typically from 225 to 340 kg. See https://www.napoleon-series.org/military/OrdnanceJournal/Issue1/H04_Owen-on-Carriages.pdf.

MFS039: “[In the] 1550s, the German heavy cavalrymen had virtually completely discarded the lance in favor of a pair or more of wheellock pistols. They were considered heavy cavalry, in full or three-quarter armor, but using their pistols as their primary offensive weapons” (Frye n.d.).

MFS040: For a lance-armed cataphract, I assume appearance in the year of 1000 (realistically—earlier, but 1000 CE for the purposes of this research), attacking at gallop (40 kph = 11.1 mps). For other details, see Note MFS010a.

MFS041: Knight of 1100 CE. Protection by armor (see Note MFS004, pp. 267, 269) from a Turkish bow implies KE of about 80 J; also see Note MFS011a; overall I assume 160 J (i.e., armor protected from 80 J plus incapacitation without armor requires 80 J). Considering the early stages of a knight's equipment development (e.g., lack of support for the lance, and so on.), I assume the lower level of KE—277 J. System mass: 620 kg, see Note MFS010a. However, if the knight had an assistant (who followed the knight on the battlefield but generally did not act as a primary fighter), assume an additional horse (500 kg) and rider (50 kg) with light armor and equipment of total (40 kg); the total mass of the system then becomes 1210 kg. Other details, see Note MFS040.

MFS042: Dismounted knight of 1100 CE. In this case, the assistant and horses were no longer a necessary part of the tactical system, but rather of the logistics train. Protection is the same as per Note MFS041, 160 J. Rate: assume the dismounted knight could continue to attack with a lance every 30 s, if multiple targets presented themselves. System mass (see Note MFS010a): person 50 kg, armor and weapons 40 kg, total 90 kg.

MFS043: Knight of 1350 CE. Protection (see Note MFS004, pp. 271–274) of full plate armor suite; also see Note MFS011a; overall I assume 265 J. System mass: 620 kg, see Note MFS010a. However, if the knight had an assistant (who followed the knight on the battlefield but generally did not act as a primary fighter), assume an additional horse (500 kg) and rider (50 kg) with light armor and equipment of total (40 kg); the total mass of the system then becomes 1210 kg. Other details, see Note MFS040.

MFS044: Dismounted knight of 1350 CE. In this case, assistant and horses were no longer a necessary part of the tactical system, but rather of the logistics train. Protection is the same as per Note MFS043, 265 J. Rate: assume the dismounted knight could recover for another attack within 5 min. System mass (see Note MFS010a): man 50 kg, armor and weapons 40 kg, total 90 kg.

MFS046: I characterize the Polish winged hussar as essentially a 13th-century knight with an assistant, with lance as a primary weapon, almost fully armored. Also see Note MFS033.

MFS047: I consider a Reiter (see Wikipedia "Reiter") as a variation on a pistol-armed knight of the mid-16th century, with somewhat lighter armor and without an assistant.

MFS048: I consider the harquebusier (see Wikipedia "Harquebusier") of the early 17th century (taken as 1620) as light armored at 160 J of protection and with armament that is an interpolation between a light harquebus (which they often could fire only once at the beginning of the engagement and produced about 1600 J KE) and a sword/saber that produced about 100 J per hack (see data for gladius in Note MFS005). I take this intermediate effect as corresponding to about 500 J, and assign an artificial projectile mass and velocity to account for this. I assume that the maximum rate of sword blows could reach 30 per minute.

MFS049: I model the cuirassier of Napoleonic times (see Wikipedia "Cuirassier") as a light-armored fighter (protection of 160 J; although the primary cuirass provided much better protection, the rest of the body and the horse had no protection), with a sword that produced about 100 J per hack (see data for gladius in Note MFS005). I assume that the maximum rate of sword blows could reach 30 per minute.

MFS050: From Fish and Scharre (2018):

Although the US Army recommends the fighting load of 50 lb, it is routinely exceeded in practice. As of 2017, the torso armor plus helmet were about 40 lb (according to other sources: 33 lb). It is being replaced by newer system that would weigh 27 lb.

MFS051: For level of protection by modern body armor, see https://en.wikipedia.org/wiki/Bulletproof_vest.

MFS052: From Norris (2011):

- p. 70: Mid-1500s, the falcon and saker had point-blank ranges of 320 and 360 yd, respectively; extreme range: 1280 and 1440 yd.
- p. 73: By 1700, projectiles of 30–200 lb were fired to ranges of up to 2000 m.
- p. 75: The regimental piece or leather gun of Gustavus Adolphus was 620 lb and could be handled by tow or even one horse.
- p. 77: Around 1630, a 24-pounder required 20 horses to move the piece and 12 horses for supporting wagons.
- p. 79: Before Sweden invaded Germany [*Data compiler's note: about 1630*], artillery was essentially immobile on the battlefield. In about 1680, trail wheels (predecessor of limber) were fitted commonly to gun carriages, enabling movement on the battlefield.

- p. 92: Mid-1600s, the average gun could fire 15 shots an hour. Inaccurate beyond 300 paces.
- p. 97: In mid-1750s, Austrian artillery standardized to 3-, 6-, and 12-pounder guns, and 7- and 10-pounder howitzers.
- p. 110: In 1781, American 56 pieces fired 3600 rounds in a day.
- p. 110: The de Gribeauval 12-pounder was lighter than the old version and was pulled by six horses. The Austrian 12-pounder of Frederic the Great (mid-1700s) era required 10 horses.
- p. 116: There was a belief that one crew member was required for every 500 lb in the gun. Usually far more.
- p. 120: In 1800, effective range of 9-pounder was half a mile. battle ranges were a few hundred meters. The canister against infantry could be used at 500 m maximum.
- p. 129: Cohorn mortars were light enough to be carried by two people. Fired shells of 3.5 kg to 750 m.
- p. 130: A Napoleonic 12-pounder was pulled by 6 to 8 horses; 6- and 4-pounders pulled by 4 to 6 horses.
- p. 147: Civil War, "Napoleon 1857", crew 5–6 men, 2 aimed solid shots per minute or 4 canister shots per minute.
- p. 149: Rodman 3-inch ordnance rifle; accurate to a mile; barrel weight 830 lb, carriage 540 lb; ordnance shell 7.5 lb, and case and canister 10.5 and 10 lb.
- p. 152: In 1870 siege of Paris, Prussians fired 199 rounds per gun per day. Smoothbores were still in some use, accurate to 1000 m.
- p. 160–161: The Krupp 77-mm Model 1897 was an inferior peer of the French 75 mm. The 75's shell was 5.3 kg.
- p. 165–166: British 13-pounder: weight 2200 lb, shrapnel shell 5.7 kg with muzzle velocity 510 mps; caliber 76.2 mm; crew of six, 20 rounds per minute.
- Modern self-propelling guns: French Caesar 155 mm (5-person crew); German PzH2000, 155 mm; French GCT; British AS90; US M-109; Czech DANA.

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- p. 199: WW2 British 17-pounder, 17 lb armor-piercing (AP) shot, caliber 3 inch; crew 5; weight 6700 lb, muzzle v = 950 m; 10 rounds per min (not common); penetration 9 inches at 1000 m.

MFS053: From Comparato (1965):

p. 123–124: By 1941, the US field artillery was reduced to division artillery (75-, 195-, and 155-mm howitzers) plus couple large Corps artillery howitzers. The 75-mm howitzer was towed by a quarter-ton truck; max range 9610 yd with high explosives (HE). The 155-mm M1 was towed by a 4-ton cargo truck. Max range was 16355 yd with HE. Another 155-mm howitzer M2 “Long Tom” was towed by a 7.5-ton truck. Max range 25715 yd.

p. 221: A single horse can pull 500–800 lb; six horses could pull no more than 3900 lb, the weight of a 3-inch gun complete with carriage and limber.

MFS054: From Guilmartin (2003):

- p. 270: Development of small arms influenced warfare not through the increase in firepower but in reducing training requirements. Spain could easily replace lost harquebusiers, but Turkey could not replace recurved composite bow archers.

- p. 271: Battles where field artillery started to play role are Hussites, Ravenna 1512, Tchaldiran 1514, Marignano 1515, Merj Dabik 1516, and Ridanieh 1517.

- p. 278: English development of the technique for producing cast-iron guns was a major turning point, costs dropped and the quantity of cannons could be increased dramatically.

- p. 323: 16th-century naval guns:

    - 30- to 40-pounder full cannon, 5500 lb [*Data compiler’s note: ratio of 157*]

    - 7- to 10-pounder sacre, 1800 lb [*Data compiler’s note: ratio of 211*]

    - 15- to 18-pounder pedrero, stone ball, lighter construction, 1200 lb

    - 52- to 55-pounder cannon, 5500 lb [*Data compiler’s note: ratio of 103*]

    - 12-pounder aspidi, 1200 lb [*Data compiler’s note: ratio of 100*]

    - 5- to 6-pounder falconet, 900 lb [*Data compiler’s note: ratio of 163*]

- 40- to 50-pounder full cannon, 6000 lb [*Data compiler's note: ratio of 133*]
- 7- to 13-pounder sacre, 1500–1800 lb [*Data compiler's note: ratio of 214–138*]
- 4- to 5-pounder half sacre, 1000 lb [*Data compiler's note: ratio of 222.*]
- 25-pounder cerbatana, 2500 lb, stone ball [*Data compiler's note: average is about 160 lb of barrel weight for 1 lb of projectile.]*

MFS055: From Ogorkiewicz (1970):

- p. 311: The conventional tank gun reached a practical limit at 120 mm and a 3000-fps muzzle velocity increase from 37 to 120 mm corresponds to a projectile weight from 1.5 to 60 lb; gun weight is about 100 times the weight of the projectile.
- p. 307: At the eve of WW2, light-medium tanks of 10–20 tons had guns of 37–47 mm caliber, 32–52 calibers long, with muzzle velocities of 2000–2800 fps, penetrating 40–60 mm plate at normal impact.
- p. 310: At the end of WW2, medium tanks had 75–85 mm guns with 2600–3000 fps muzzle velocity. In late 1940s: 90–100 mm with 2800–3000 fps.
- p. 322: A common approach is to make the front of a tank immune to the gun of the similar hostile tank at 500–1000 yd.

MFS056: From Manucy (1994):

- p. 7: Gustavus Adolphus, about 1630, developed a cast-iron 4-pounder, weight 500 lb, two horses pulled it in the field, served by three crew.
- p. 10: Guns of the American Revolution had side boxes on each side of field carriage, holding 21 rounds each.
- p. 12: During the Mexican War, the 12-pounder field howitzer was 788 lb.
- p. 19: During the Civil War, smoothbores were effective to 600–700 yd, but the max distance of a shot was 1600–2600 yd.
- p. 34: "Beyond blank range, the gunner was never sure of hitting his target." Point-blank ranges are listed as falcon (3–4 lb ball), 417 yd; pasavolante (1–15 lb ball, 6 lb popular), 500 yd; media sacre (5–7 lb ball), 417 yd.

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- p. 52: Shows that even in 1866, US naval smoothbores point-blank ranges were 300–350 yd.
- p. 52: In the 18th century, a 24-pounder cannon developed a muzzle velocity of 700 fps.

MFS057: From Hall (1997):

- p. 19: A longbow arrow lost its force beyond 150 m. At 60 m to as much as 120 m, the arrow's KE was still sufficient to pierce mail, leather, and low-grade plate armor.
- p. 42: Gunpowder arrived from Asia as a well-developed technology.
- p. 137: Muzzle velocity of artillery shot was similar to small-bore bullets. Late 18th century: 344–437 mps; 6-pounder produced 508 mps with a charge of 1/3 of ball weight. Civil War American: 6- and 12-pounder, 440 to 460 mps.
- p. 138: Early modern weapons were lethal only up to 120 m. In 16th–17th centuries, with some form of body armor, the lethal zone was only 25–30 m.
- p. 153: In 1860s, fire was advisable at 1000 yd at most and became truly effective at 600–700 yd. In the 18th–19th centuries, two solid shots per minute was maximum. Would carry enough ammunition to keep this rate for about an hour. Late in the 17th century, Vauban recommended no more than 100 rounds per gun per day (i.e., 8 rounds per hour). Austrians advised only 4 per hour.
- p. 193: Reiter could shoot three pistols before retiring to reload. Pistols were effective only at 5 m. [*Data compiler's note: Assume that cyclical rate of fire was about 5, i.e., the Reiter would take as little as 12 s between firing their three pistols successively.]*
- pp. 196–197: Heavy cavalry armed with lances was put out of business by mounted pistoleers. The latter had the same mobility, higher lethality, and could kill a lancer while remaining outside of their lance's range. Lancers, however, were still effective against an infantryman with a firearm, because the infantryman could not escape the lance.

MFS058:

- System: Mark IV

- Sources:
    - https://en.wikipedia.org/wiki/Mark_IV_tank
    - Macksey (1988, p. 22)
- Year: 1917
- Projmass: 2.7 kg, 57 mm
- Velocity: 411 mps
- Effrange: 6675 m—highly questionable, comes from the description of the naval version. In general, even in WW2, the typical engagement range was under 1000 m. Macksey (1988, pp. 36–37) describes engagements at up to 1000 m in 1918; I assume a 1500-m maximum.
- Rate: The gun is capable of 25 rounds per min, the tank had two guns capable of 50 rounds per minute.
- Protection: max 12 mm, which had probability of 0.30 to be penetrated by a German antitank rifle round K-bullet, 12.1 g at 820 mps, 7.92 × 57; but easily penetrated by a T-Gewehr.
- Sysmass: 32000
- HP: 105
- Crew: 8

MFS059:

- System: 1918 T-Gewehr antitank rifle
- Year: 1918
- Projmass: 51.5 g
- Velocity: 785 mps, penetration 26 mm at 100 m, 18 mm at 500 m
- Effrange: 500 m
- Rate: 5, assumed (single shot loading, somewhat lower than a rate common for late 19th-century single shot breech loaders)
- Protection: none
- Sysmass: 18.5 kg plus crew and ammo and other equipment (90 × 2 + 18.5)
- HP: crew, 0.2 hp

- Crew: 2

MFS060:

- System: FT tank
- Source: Macksey (1988, pp. 28–41)
- Year: 1917
- Projmass: 0.67 kg, 37 mm, based on the partly comparable https://en.m.wikipedia.org/wiki/Canon_d%27Infanterie_de_37_modèle_1916_TRP.
- Velocity: 600 mps
- Effrange: 1500 m (assumed, consistent with Mark IV)
- Rate: 15
- Protection: 22-mm armor, marginally protected from T-Gewehr
- Sysmass: 6500
- HP: 39
- Crew: 2

MFS061:

- System: Vickers 6 ton
- Sources:
    - https://en.m.wikipedia.org/wiki/Vickers_6-Ton
    - Macksey (1988, pp. 46–49)
- Year: 1928
- Projmass: 47-mm gun, 1.47 kg
- Velocity: 560 mps
- Effrange: 1500 m (also compare to the Char B and Somua S35)
- Rate: 20
- Protection: 25-mm armor (better than the T-Gewehr but worse than own gun?). Assume 30000 J.
- Sysmass: 7300
- HP: 98

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- Speed: max was 35 kph, assume offroad half of that, 17 kph
- Crew: 3

MFS062:

- System: T-26
- Sources:
    - https://en.m.wikipedia.org/wiki/T-26
    - Macksey (1988, pp. 58–59)
- Year: 1931
- Projmass: 1.43 kg
- Velocity: 760 mps
- Effrange: 1500 m
- Rate: 15
- Protection: 15 mm; effective against a German antitank rifle round K-bullet 12.1 g at 820 mps, 7.92 × 57; but not a T-Gewehr
- Sysmass: 9600
- HP: 90
- Crew: 3
- Offroad speed: 16 kph

MFS063:

- System: Char B1 bis tank
- Sources:
    - https://en.m.wikipedia.org/wiki/Char_B1
    - Macksey (1999, pp. 62–78)
- Year: 1934
- Projmass: 1.7 kg (47 mm)
- Based on the somewhat better https://en.m.wikipedia.org/wiki/47_mm_APX_anti-tank_gun.
- Velocity: 855 mps

- Effrange: 1000 m (2000 m according to Wikipedia; however, the same article mentions the ability to defeat 60-mm armor at 550 m; also per Macksey (1988, p. 78), the SOMUA S35 gun fails at 1000 m against the Pz III.)
- Rate: 15
- Protection: 60 mm; effective against a 47-mm antitank gun (see reference for antitank gun above; 1.47-kg projectile at 855 m/s) and German 37-mm tank gun
- Sysmass: 28000
- HP: 272
- Crew: 4
- Offroad speed: 21 kph

MFS064:

- System: SOMUA S35 tank
- Sources:
    - https://en.m.wikipedia.org/wiki/SOMUA_S35
    - Macksey (1988, pp. 68–78)
- Year: 1935
- Projmass: 1.47 kg, assume same gun as Char B1 bis. Claimed to penetrate any German tank armor of May 1940, at 1000 m, per https://en.m.wikipedia.org/wiki/SOMUA_S35.
- Velocity: 855 mps
- Effrange: 1000 m (per Macksey [1988, p. 78], fails at 1000 m against the Pz III.)
- Rate: 15
- Protection: 47-mm armor, assume KE half of the Char B1 bis; 270000 J.
- Sysmass: 19200
- HP: 190
- Crew: 3

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- Offroad speed: Wikipedia reports 41 km/h on road and 32 offroad—not likely. I assume 16 kph comparable to other tanks of mid-1930s.

MFS065:

- System: T-34 tank of 1941
- Sources:
    - https://en.m.wikipedia.org/wiki/T-34
    - Macksey (1988, pp. 83–94)
- Year: 1940
- Projmass: 6.5 kg (https://en.m.wikipedia.org/wiki/76_mm_tank_gun_M1940_F-34)
- Velocity: 680 mps
- Effrange: at 1000 m, it could penetrate 60-mm armor; also see Macksey (1988 p. 102); I judge it was effective at 1500 m against the Pz III and Pz IV of the 1941 vintage.
- Rate: 5–10
- Protection: 52-mm armor, marginally threatened by a 5-cm KwK 39 gun; 1.06 kg at 1130 m/s (https://en.m.wikipedia.org/wiki/5_cm_KwK_39)
- Sysmass: 29200
- HP: 500
- Crew: 4

MFS066:

- System: T-34-85 tank of 1944
- Sources:
    - https://en.m.wikipedia.org/wiki/T-34
    - Macksey (1988, pp. 109–113)
- Year: 1943
- Projmass: 9.2 kg
- Velocity: 792 mps

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- Effrange: 2000 m (Macksey [1988, p. 107], claims 1500 m against a Tiger I, but I judge probably 2000 against a Pz IV, a closer matching system.)
- Rate: 10, assumed
- Protection: up to 90 mm, protected from a 5-cm KwK 39 gun; 1.06 kg at 1130 m/s (https://en.m.wikipedia.org/wiki/5_cm_KwK_39). Not quite effective against https://en.m.wikipedia.org/wiki/7.5_cm_Pak_40, which was 4.05 kg at 990 mps (1,985,000 J). Assume 2,000,000 J.
- Sysmass: 32000
- HP: 500
- Crew: 5
- Offroad speed: 20 kph (see https://ww2db.com/vehicle_spec.php?q=314)

MFS067:

- System: KV-1 of 1941
- Source: https://en.m.wikipedia.org/wiki/Kliment_Voroshilov_tank
- Year: 1939
- Projmass: 6.5 kg
- Velocity: 680 mps
- Effrange: at 1000 m, it could penetrate 60-mm armor; also see Macksey (1988, p. 102); I judge it was effective at 1500 m against the Pz III and Pz IV of the 1941 vintage.
- Rate: 5–10
- Protection: up to 90-mm armor, assume a match to the 7.5-cm Pak 40, which was 4.05 kg at 990 mps
- Sysmass: 45000
- HP: 600
- Crew: 5
- Offroad speed: 16 kph; see Green (2017, p. 175).

MFS068:

- System: Panzer IV, version H, 1943

- Sources:
    - https://en.m.wikipedia.org/wiki/Panzer_IV
    - Macksey (1988, pp. 98–99, 102)
- Based on version Ausf H, 1943
- Year: 1943
- Projmass: 4.1 kg
- Velocity: 990 mps
- Effrange: 2000 m (based on the ability to penetrate the frontal armor of a contemporary T-34/86)
- Rate: 10, conjectured
- Protection: assume almost adequate match against a contemporary T-34; say 2,000,000 J.
- Sysmass: 25000
- HP: 296
- Crew: 5
- Offroad speed: Wikipedia quotes 16 kph.

MFS069:

- System: IS-2 (most numerous built)
- Sources:
    - https://en.m.wikipedia.org/wiki/IS_tank_family#IS-3
    - Macksey (1988, pp. 143–147)
- Year: 1943
- Projmass: 122-mm gun, 25-kg projectile.
- Velocity: 804 mps
- Effrange: 2000 m (Macksey [1988, p. 147], claims 1500 m against a Panther D *[Data compiler's note: I judge about 2500 m against a Pz IV; on balance, I accept 2000 m*.])
- Rate: 3 per min; some sources mention "poor rate of fire" of 5 rounds per min; or half of the T-34

- Protection: 100-mm armor. A match to Tiger II.
- Sysmass: 46000
- HP: 600
- Crew: 4

MFS070:

- System: Sherman Firefly tank
- Source: https://en.m.wikipedia.org/wiki/Sherman_Firefly
- Year: 1943
- Projmass: APDS: 3.5 kg
- Velocity: 3950 fps
- Effrange: 2500 m (could penetrate even the thickest armor of opponents)
- Rate: 5 (assume the slower rate of a Sherman, due to the crowded turret)
- Protection: assume a match to a 7.5-cm Pak 40, which was 4.05 kg at 990 mps
- Sysmass: 45000
- Sysmass: 35300
- HP: 425
- Crew: 4
- Offroad speed: 17–32 kph; see https://ww2db.com/vehicle_spec.php?q=314, assume 25 kph

MFS071:

- System: M4 Sherman tank
- Sources:
    - https://en.m.wikipedia.org/wiki/M4_Sherman
    - Macksey (1988, pp. 134–143)
- Year: 1940
- Projmass: 6.32 kg
- Velocity: 619 mps

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- Effrange: 2000 m (Macksey 1988, p. 102)
- Rate: 15
- Protection: match to a Pz IV
- Sysmass: 30300
- HP: 350
- Crew: 5
- Offroad speed: 17–32 kph; see https://ww2db.com/vehicle_spec.php?q=314, assume 25 kph

MFS072:

- System: M26 Pershing tank
- Sources:
    - https://en.m.wikipedia.org/wiki/M26_Pershing
    - Hanger (2018)
    - Macksey (1988, pp. 143–147)
- Year: 1944
- Projmass: 10.9 kg
- Velocity: 1200 mps
- Effrange: 2000 m (Macksey [1988, p. 147]; against a Panther D)
- Rate: 8
- Protection: 102-mm armor. Match to a Panther and Tiger I but not a Tiger II (Hanger 2018)
- Sysmass: 41700
- HP: 450
- Crew: 5
- Offroad speed: 8 km/h (per Wikipedia)

MFS073:

- System: Panther tank

- Sources:
    - https://en.m.wikipedia.org/wiki/Panther_tank
    - Macksey (1988, pp. 132–142)
- Year: 1943
- Projmass: 7.2 kg
- Velocity: 935 mps
- Effrange: 1600 m (Macksey [1988, p. 147]; against a Sherman)
- Rate: 10, conjectured
- Protection: match to a Sherman Firefly
- Sysmass: 44800
- HP: 690
- Crew: 5
- Offroad speed: assume comparable to a T-34

MFS074:

- System: Tiger I tank
- Sources:
    - https://en.m.wikipedia.org/wiki/Tiger_I
    - Macksey (1988, pp. 120–125)
- Year: 1941
- Projmass: 10.2 kg
- Velocity: 773 mps
- Effrange: 2000 m (Macksey [1988, p. 107], shows 1500 m against a T34/85, Sherman M4A1; however, these are later than 1941.)
- Rate: 15, assumed
- Protection: 120-mm armor max. Meets its match in the IS-2 and M26 Pershing
- Sysmass: 57000
- HP: 700

- Crew: 5
- Speed offroad: 20 kph

MFS075:

- System: Tiger II
- Year: 1943
- Projmass: 7.3 kg
- Velocity: 1130 mps
- Effrange: 2500 (Macksey [1988, p. 147]; against a Sherman; or 1800 m against a Pershing)
- Rate: 15, assumed
- Protection: 185-mm armor max. Exceeds protection of the IS-2 and M26 Pershing? Meets its match in the Soviet 122-mm gun. Also in the Sherman Firefly, possibly.
- Sysmass: 68500
- HP: 700
- Crew: 5
- Speed offroad: 15 kph

MFS076:

- System: 7.5 cm Pak 40 antitank gun
- Source: https://en.m.wikipedia.org/wiki/7.5_cm_Pak_40
- Year: 1941
- Projmass: 4.05 kg
- Velocity: 990 mps
- Effrange: 1800 m for direct fire
- Rate: 14
- Protection: gun shield protects against rifle fire; about 3000 J
- Sysmass: 1425

- HP: required artillery tractor, possibly https://en.m.wikipedia.org/wiki/Sd.Kfz._11), with 100 hp and weight 7200 kg; add 1000 kg for crew and ammo; total 9625.
- Crew: 6

MFS077:

- System: Napoleon 1857 gun
- Sources:
    - Civil War Napoleon gun, see https://en.m.wikipedia.org/wiki/Field_artillery_in_the_American_Civil_War
    - https://en.m.wikipedia.org/wiki/Canon_obusier_de_12
- Year: 1857
- Projmass: 12.3 lb (5.57 kg)
- Velocity: 1440 fps
- Effrange: 1480 m at 5° elevation (but per Note MFS056, p. 19, during the Civil War, smoothbores were effective to 600–700 yd; and per Note MFS148, the effective range was 1600 m.)
- Rate: 2 per minute, assumed
- Protection: unarmored
- Sysmass: gun tube alone was 1227 lb. Gun with carriage was 1200 kg. Gun plus limber was 1750 kg. Drawn by six horses of about 500 kg weight each. Plus assume eight gunners 800 kg. Then the total is 1750 + 3000 + 800 = 5550 kg.
- HP: 6.8
- Crew: stated as 4? Sounds low, perhaps 8.

MFS077a:

- System: Napoleon gun of 1857 (HA)
- Sources:
    - Civil War Napoleon gun, see https://en.m.wikipedia.org/wiki/Field_artillery_in_the_American_Civil_War
    - https://en.m.wikipedia.org/wiki/Canon_obusier_de_12

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- Year: 1857
- Projmass: 12.3 lb (5.57 kg)
- Velocity: 1440 fps
- Effrange: 1480 m at 5° elevation (but see Note MFS056, p. 19, during the Civil War, smoothbores were effective to 600–700 yd.)
- Rate: 2 per minute, conjectured
- Protection: unarmored
- Sysmass: 5550 kg plus 5000 kg extra horses and 180 kg extra crew; total 10730 kg
- HP: 17 hp
- Crew: 10

MFS078:

- System: 10-pounder Parrott Rifle
- Sources:
    - https://web.archive.org/web/20090106045327/http://civilwartalk.com/Resource_Center/Arms_and_Ordnance/Field_Artillery/artillery-profile-10-pdr-parrott-rifle-a11.html
    - https://en.m.wikipedia.org/wiki/Parrott_rifle
    - https://en.m.wikipedia.org/wiki/Field_artillery_in_the_American_Civil_War
    - Also see Note MFS056, p. 56.
- Year: 1860
- Projmass: 10 lb
- Velocity: 1230 fps (per Note MFS150, some version—1809 fps)
- Effrange: 1900 yd at 5° elevation
- Rate: 2, assumed
- Protection: unarmored
- Sysmass: tube was 890 lb. Assume the rest like in Napoleon 1857. Total 5400 kg.

- HP: assume eight horses pulling the gun; total 8.8 hp
- Crew: 8

MFS078a:

- System: 10pdr Parrott Rifle (HA)
- Sources:
    - https://web.archive.org/web/20090106045327/http://civilwartalk.com/Resource_Center/Arms_and_Ordnance/Field_Artillery/artillery-profile-10-pdr-parrott-rifle-a11.html
    - https://en.m.wikipedia.org/wiki/Parrott_rifle
    - https://en.m.wikipedia.org/wiki/Field_artillery_in_the_American_Civil_War
    - Also see Notes MFS056, p. 56, and MFS096.
- Year: 1860
- Projmass: 10 lb
- Velocity: 1230 fps
- Effrange: 1900 yd at 5° elevation
- Rate: 2, assumed
- Protection: unarmored
- Sysmass: 5400 kg plus 5000 kg extra horses and 180 kg extra crew; total 10580 kg
- HP: 19 hp
- Crew: 10

MFS079:

- System: T-72 tank
- Source: https://janes.ihs.com/ArmouredFightingVehicles/Display/jaa_0055-jafv#T-72B1 and https://en.wikipedia.org/wiki/125_mm_smoothbore_ammunition
- Year: 1972
- Projmass: assume ammunition comparable to 3BM15; 3.9 kg without sabot

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- Velocity: 1785 mps
- Effrange: 3000 m
- Rate: 8
- Protection: assume match to the early Abrams M1 or M60
- Sysmass: 42500
- HP: 780
- Crew: 3
- Offroad speed: 45 kph; see https://fas.org/man/dod-101/sys/land/row/t72tank.htm

MFS080:

- System: M1 Abrams
- Source: https://janes.ihs.com/ArmouredFightingVehicles/Display/jaa_0084-jafv
- Year: 1979
- Projmass: see notes on the M60
- Velocity: see notes on the M60 and also https://en.m.wikipedia.org/wiki/Royal_Ordnance_L7
- Effrange: 2000 m
- Rate: 6 (https://fas.org/man/dod-101/sys/land/docs/4lastmbt.pdf)
- Protection: assume match to the T-72 or at least the Tiger II
- Sysmass: 54000
- HP: 1500
- Crew: 4

MFS081:

- System: 17-pounder antitank towed gun
- Sources:
    - https://www.junobeach.org/canada-in-wwii/articles/artillery/royal-canadian-artillery-organization/

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- https://en.m.wikipedia.org/wiki/Ordnance_QF_17-pounder
    - Macksey (1988, p. 129)
- Year: 1942
- Projmass: 3.4 kg (17 lb AP shot, per Note MFS052, p. 199)
- Velocity: 1200 mps (950 per Note MFS052, p. 199)
- Effrange: 1500 m (1000 m per Note MFS052, p. 199)
- Rate: 20 (10 per Note MFS052, p. 199)
- Protection: gun shield protected against rifles
- Sysmass: complete gun with limber,3050 kg; towed by M3 half-track of 9070 kg; plus 1000 kg for crew, and so on.
- HP: 147
- Crew: 6 (5, per Note MFS052, p. 199)

MFS082:

- System: 6-pounder antitank towed gun
- Source: https://en.m.wikipedia.org/wiki/Ordnance_QF_6-pounder
- Year: 1940
- Projmass: 1.42 kg
- Velocity: 1219 mps
- Effrange: 1500 m
- Rate: 15
- Protection: shield against rifle fire
- Sysmass: gun itself 1140 kg, towed by a 2500-kg Dodge track; plus 1000 kg for crew and so on.
- HP: 92
- Crew: 6

MFS087:

- System: Centurion tank

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- Sources:
    - https://en.wikipedia.org/wiki/Centurion_(tank)
    - https://wiki.warthunder.com/index.php?title=Royal_Ordnance_L7#Ammunition
    - Macksey (1988, pp. 158–166)
- Year: 1946
- Sysmass: 52000
- HP: 650
- Crew: 4
- Protection: up to 152-mm armor; match to the Panther and Tiger
- Projmass: 5.8 kg
- Velocity: 1478 mps
- Rate of fire: 10
- Effrange: 2000 m
- Offroad speed: assume half of top speed which is claimed as 35 kph; that is 17 kph

MFS088:

- System: Chieftain tank
- Sources:
    - https://en.wikipedia.org/wiki/Chieftain_(tank)
    - https://en.wikipedia.org/wiki/Royal_Ordnance_L11A5#Available_ammunition
    - Macksey (1988, p. 173)
- Year: 1965
- Sysmass: 56000
- HP: 750
- Crew: 4
- Protection: up to 195-mm armor; match to T-54/55

- Projmass: 7.6 kg
- Velocity: 1370 mps
- Rate of fire: 10
- Effrange: 3000 m
- Offroad speed: 30 kph

MFS089:

- System: Challenger 1 tank
- Source: https://en.wikipedia.org/wiki/Challenger_1
- Year: 1982
- Sysmass: 70000
- HP: 1200
- Crew: 4
- Protection: assume a match comparable to the T-72
- Projmass: 4 kg (4-kg penetrator only; data taken from modern round by GD, see https://www.gd-ots.com/munitions/large-caliber-ammunition/120 mm-kew-a1/.)
- Velocity: 1740 mps
- Rate of fire: 10 (assume same as Chieftain)
- Effrange: 3000 m (see https://en.wikipedia.org/wiki/Royal_Ordnance_L11A5)
- Offroad speed: assume half of top on-road speed of 56 kph; that is 28 kph; or 30 kph as Chieftain

MFS090:

- System: M48 Patton tank
- Sources:
  - https://en.wikipedia.org/wiki/M48_Patton
  - https://en.wikipedia.org/wiki/90_mm_Gun_M1/M2/M3
  - Macksey (1988, pp. 154–165)

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- Year: 1953
- Sysmass: 45000
- HP: 650
- Crew: 4
- Protection: compare to T-54
- Projmass: 10.9 kg
- Velocity: 1200 mps
- Rate of fire: 32 (according to https://en.wikipedia.org/wiki/ 90_mm_Gun_ M1/M2/M3)
- Effrange: 2000 m
- Offroad speed: assume half of top road speed of 42 kph, that is 21 kph

MFS091:

- System: M60 tank
- Sources:
    - https://en.wikipedia.org/wiki/M60_Patton
    - https://en.wikipedia.org/wiki/Royal_Ordnance_L7
    - https://www.army-technology.com/projects/m60/
    - Projectile weight and muzzle velocity are from http://www.pof.gov.pk/catalouge/Anti_Tank_Ammo.pdf
    - Macksey (1988, p. 169)
- Year: 1960
- Sysmass: 46000
- HP: 750
- Crew: 4
- Protection: assume a match to T-54/55
- Projmass: 6.12 kg
- Velocity: 1490 mps
- Rate of fire: 10

- Effrange: 2500 m (assumed higher than the M48)
- Offroad speed: Quoted as 10 mph (see https://www.army-technology.com/projects/m60/)

MFS092:

- System: T-54/T-55 tank
- Sources:
    - https://en.wikipedia.org/wiki/T-54/T-55#T-54
    - https://fas.org/man/dod-101/sys/land/row/t54tank.htm
    - Macksey (1988, pp. 155–164)
- Year: 1949
- Sysmass: 36000 (T-55)
- HP: 500 (early versions)
- Crew: 4
- Offroad speed: 35
- Protection: match to the M48 Patton
- Projmass: (assume a D-10S gun) 15.6 kg
- Velocity: 1000 mps
- Rate of fire: 6
- Effrange: 2000 m

MFS093:

- System: T-64 tank
- Sources:
    - https://janes.ihs.com/ArmouredFightingVehicles/Display/jaa_0056-jafv
    - https://en.wikipedia.org/wiki/T-64
    - https://fas.org/man/dod-101/sys/land/row/t64tank.htm
    - https://en.wikipedia.org/wiki/2A46_125_mm_gun
- Year: 1964

- Sysmass: 38000 (T-64A)
- HP: 700
- Crew: 3
- Offroad speed: assume 30 km/h; half of maximum road speed, which is quoted as 60 km/h
- Protection: assume to match the armament of the M60
- Projmass: 125-mm smoothbore D-81T(aka 2A46) 7.05 kg
- Velocity: 1750 mps
- Rate of fire: 8
- Effrange: 3000 m

MFS094:

- System: T-80
- Sources:
    - https://janes.ihs.com/ArmouredFightingVehicles/Display/jaa_0053-jafv
    - https://en.wikipedia.org/wiki/T-80
    - https://fas.org/man/dod-101/sys/land/row/t80tank.htm
    - https://en.wikipedia.org/wiki/2A46_125_mm_gun
- Year: 1976 or 1987 (T-80U)
- Sysmass: 46000
- HP: 1250
- Crew: 3
- Offroad speed: 48 mph
- Projmass: assume comparable to 3BM44 “Mango”, 4.85 kg
- Velocity: 1715 mps
- Rate of fire: 8
- Effrange: 3000–4000 m

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MFS095:

- System: Abrams M1A1 tank
- Sources:
  - https://janes.ihs.com/ArmouredFightingVehicles/Display/jaa_0084-jafv
  - https://en.wikipedia.org/wiki/M1_Abrams
  - https://fas.org/man/dod-101/sys/land/m1.htm
  - https://en.wikipedia.org/wiki/M829#M829A3
- Year: 1986
- Sysmass: 67600
- HP: 1500
- Crew: 4
- Offroad speed: 30 mph (48 kph)
- Protection: assume a match to the T-80 or its own armament
- Projmass: See Note MFS095a. Assume comparable to the Soviet 3BM32; 4.85 kg.
- Velocity: 1700 mps
- Effrange: 3000–4000 m

MFS095a:

Because the open source data for Western tanks of the last 30–40 years tend to be scarce and contradictory, and because the open source data on Soviet and Russian KE rounds are somewhat more plentiful (albeit of uncertain veracity), I use them as a crude approximation for Western tanks of the same period.

See https://en.wikipedia.org/wiki/125_mm_smoothbore_ammunition

MFS096:

- System: Canon de 8 Gribeauval
- Sources:
  - https://en.wikipedia.org/wiki/Canon_de_8_Gribeauval
  - https://en.wikipedia.org/wiki/Gribeauval_system

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- Year: 1765
- Sysmass: barrel, carriage, and limber total 1431 kg. To this, add four horses (2000 kg). And crew with their equipment (100 kg per person, 13 crew = 1300 kg; they walked, did not ride). Grand total of the system: 4731 kg. Limber probably included 15 rounds.
- HP: 4 horses
- Crew: 11–13
- Protection: none
- Projmass: 8.6 lb
- Velocity: 390 mps (per Note MFS057, p. 137, assume an average of the range of 344–437 mps)
- Rate of fire: 2
- Effrange: 800 m

MFS096a:

- System: Canon de 8 Gribeauval–horse artillery
- Sources: I assume this system to be a horse artillery version of the one in Note MFS096. Horse artillery organization, particularly the number of additional horses and crew members in comparison to foot artillery, varied significantly from nation to nation and over time. I take the following simplifying assumptions, based on generalizations from French et al. (1864), van Uythoven and Zhmodikov (2013), and Summerfield (2013): horse artillery required additional 10 horses per gun as compared to foot artillery and 2 additional crew members (horse handlers). The offroad speed is assumed to be a trot, which is 13–19 kph, and I assume 15 kph.
- Year: 1790 (assume 1790s when the horse artillery became commonly accepted)
- Projmass: 8.6 lb
- Velocity: 390 fps
- Effrange: 800 m
- Rate: 2
- Protection: none

- HP: 4 plus 10 gives 14 horses, plus crew; total 15.5 hp
- Crew: 13 plus 2 = 15
- Sysmass: 4731 plus 10 additional horses (5000 kg) and 2 crew (180 kg); total 9911 kg
- Offroad speed: 15 kph

MFS098:

- System: Canon de 12 Gribeauval
- Sources:
    - https://en.wikipedia.org/wiki/Canon_de_12_Gribeauval
    - https://en.wikipedia.org/wiki/Gribeauval_system
- Year: 1765
- Sysmass: barrel, carriage, and limber total 1823 kg. To this, add six horses (3000 kg) and a crew with their equipment (100 kg per person, 15 crew = 1500 kg; they walked, did not ride). Grand total of the system: 6323 kg.
- HP: 6 horses
- Crew: 15
- Offroad speed: 5 kph
- Protection: none
- Projmass: 13 lb
- Velocity: 390 fps (see Note MFS096)
- Rate of fire: 2
- Effrange: 900 m

MFS098a:

- System: Canon de 12 Gribeauval (HA)
- Sources:
    - https://en.wikipedia.org/wiki/Canon_de_12_Gribeauval
    - https://en.wikipedia.org/wiki/Gribeauval_system; see comments in Note MFS096.

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- Year: 1790
- Sysmass: 6323 kg plus extra 5000 kg horses and 180 kg crew; total 11503 kg
- HP: 17.7 hp
- Crew: 17
- Offroad speed: 15 kph
- Protection: none
- Projmass: 13 lb
- Velocity: 390 fps
- Rate of fire: 2
- Effrange: 900 m

MFS099:

- System: Canon de 4 Gribeauval
- Sources:
    - https://en.wikipedia.org/wiki/Canon_de_4_Gribeauval
    - https://en.wikipedia.org/wiki/Gribeauval_system
- Year: 1765
- Sysmass: barrel, carriage, and limber total 884 kg. To this, add four horses (2000 kg) and a crew with their equipment (100 kg per person, 8 crew = 800 kg; they walked, did not ride). Grand total of the system: 3684 kg.
- HP: 4 horses (per MFS148—3 horses)
- Crew: 8
- Protection: none
- Projmass: 4 times 489 g
- Velocity: 390 mps (see Note MFS096)
- Rate of fire: 2–3
- Effrange: 700 m

MFS099a:

- System: Canon de 4 Gribeauval (HA)
- Sources:
    - https://en.wikipedia.org/wiki/Canon_de_4_Gribeauval
    - https://en.wikipedia.org/wiki/Gribeauval_system
- Year: 1790
- Sysmass: 3684 kg plus 5000 kg extra horses and 180 kg extra crew
- HP: 15
- Crew: 10
- Offroad speed: 15 kph
- Protection: none
- Projmass: 4 times 489 g
- Velocity: 390 mps (see Note MFS096)
- Rate of fire: 2–3
- Effrange: 700 m

MFS100:

- System: RBL 12-pounder 8 cwt Armstrong gun
- Sources:
    - https://en.wikipedia.org/wiki/RBL_12-pounder_8_cwt_Armstrong_gun
    - https://web.archive.org/web/20080622181737/http://riv.co.nz/rnza/hist/arm/arm2.htm
- Year: 1859
- Sysmass: the gun was "8cwt", meaning probably that the barrel was 800 lb; to this I assume I need to add 1000 lb (125% of barrel weight, based on 12-pounder Gribeauval data) of carriage and limber. This would require 4 horses (2000 kg) and assume 8 crew (800 kg). Grand total: 3610 kg.
- HP: 4
- Crew: 8

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- Offroad speed: 6 kph (foot)
- Protection: none
- Projmass: 5.44 kg
- Velocity: 378 mps
- Rate of fire: 3, conjectured
- Effrange: 3100 m

MFS100a:

- System: RBL 12-pounder 8 cwt Armstrong gun (HA)
- Sources:
  - https://en.wikipedia.org/wiki/RBL_12-pounder_8_cwt_Armstrong_gun
  - https://web.archive.org/web/20080622181737/http://riv.co.nz/rnza/hist/arm/arm2.htm
  - see Note MFS096
- Year: 1859
- Sysmass: 3610 kg plus 5000 kg extra horses and 180 kg extra crew; total 8790 kg
- HP: 15
- Crew: 10
- Offroad speed: 15 kph
- Protection: none
- Projmass: 5.44 kg
- Velocity: 378 mps
- Rate of fire: 3, conjectured
- Effrange: 3100 m

MFS101:

- System: Canon de 75 modèle 1897

- Source: https://en.wikipedia.org/wiki/Canon_de_75_mod%C3%A8le_1897
- Year: 1897
- Sysmass: weight is stated as 1544 kg. Perhaps this is without the limber, so I add 300 kg for limber; plus six horses, 3000 kg, and six crew, 600 kg. Total 5444 kg.
- HP: 6
- Crew: 6
- Offroad speed: 10 kph
- Protection: gun shield, so consider protected against the rifle fire
- Projmass: 7.25 kg
- Velocity: 500 mps
- Rate of fire: 15
- Effrange: 8500 m is stated for indirect fire; for direct fire, I assume a more realistic 1800 m that was state of the art even in WW2.

MFS103:

- System: 8.8 cm Pak 43
- Sources:
    - https://en.wikipedia.org/wiki/8.8_cm_Pak_43;
    - Macksey (1988, p. 78, 106–107, 129)
- Year: 1943
- Sysmass: the gun is listed as 4350 kg, Sd.Kfz, a 7 half-track is often mentioned as towing vehicle, which was 11500 kg with 133 hp; add 1000 kg for crew and ammo; total 16850 kg
- HP: 133
- Crew: 6, assumed
- Offroad speed: 20 kph, assumed
- Protection: rifle fire
- Projmass: 10.4 kg

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- Velocity: 1000 mps (Macksey [1988, p. 78,129]: 811–936 m/s)
- Rate of fire: 6
- Effrange: 2000 m

MFS104:

- System: Marder III
- Source: https://en.wikipedia.org/wiki/Marder_III
- Year: 1942
- Sysmass: 10670
- HP: 148
- Crew: 4
- Offroad speed: 20 kph, assumed
- Protection: barely adequate against antitank rifles
- Projmass: assume 7.5-cm Pak 40 gun; 4.05 kg
- Velocity: 990 mps
- Rate of fire: 14
- Effrange: 1800 m

MFS105:

- System: Sturmgeschütz III
- Source: https://en.wikipedia.org/wiki/Sturmgesch%C3%BCtz_III
- Year: 1940
- Sysmass: 23900
- HP: 296 hp
- Crew: 4
- Offroad speed: 20 kph, assumed
- Protection: adequate against the early T-34
- Projmass: 4.1 kg
- Velocity: 990 mps

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- Rate of fire: 14
- Effrange: 1800 m

MFS106:

- System: Jagdpanzer IV
- Source: https://en.wikipedia.org/wiki/Jagdpanzer_IV
- Year: 1943
- Sysmass: 25800
- HP: 296
- Crew: 4
- Offroad speed: 20 kph, assumed
- Protection: adequate against early T-34
- Projmass: with 7.5 cm KwK 42 gun, 4.75 kg
- Velocity: 1130 mps
- Rate of fire: assume 14
- Effrange: 3000 m

MFS107:

- System: M36 tank destroyer
- Source: https://en.wikipedia.org/wiki/M36_tank_destroyer
- Year: 1943
- Sysmass: 28600
- HP: 450
- Crew: 5
- Offroad speed: 21 kph, assumed
- Protection: adequate against Pz III
- Projmass: 10.9 kg
- Velocity: 810 mps
- Rate of fire: 32

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- Effrange: 2000 m

MFS108:

- System: SU-85
- Source: https://en.wikipedia.org/wiki/SU-85
- Year: 1943
- Sysmass: 29600
- HP: 493
- Crew: 4
- Offroad speed: 20 kph, assumed. See http://tankarchives.blogspot.com/2014/03/soviet-medium-tank-destroyers-part-2.html
- Protection: 45-mm armor, perhaps adequate against the early Pz III
- Projmass: 9.2 kg
- Velocity: 792 mps
- Rate of fire: 10
- Effrange: 1500 m

MFS109:

- System: SU-100
- Sources: Macksey (1988, p. 143–145)
- Year: 1944
- Sysmass: 31600
- HP: 500
- Crew: 4
- Offroad speed: 25 kph, assumed
- Protection: a match to the Pz IV
- Projmass: assume BR-412 round; 15.6 kg
- Velocity: 895 mps
- Rate of fire: 5

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- Effrange: 3000 m

MFS110:

- System: 100-mm antitank gun T-12
- Source: https://en.wikipedia.org/wiki/100_mm_anti-tank_gun_T-12
- Year: 1961
- Sysmass: gun is 2750 kg; towed by MT-LB APC; weight 11900; assume 1000 kg crew and ammo, for a total of 15650 kg
- HP: 240
- Crew: 6
- Offroad speed: 25 kph towed by a MT-LB
- Protection: rifle fire
- Projmass: assume 3BM23/3UBM10 round, projectile 4.55 kg
- Velocity: 1548 mps
- Rate of fire: 10
- Effrange: 3000 m

MFS111:

- System: Sprut-B smoothbore 125-mm antitank towed gun
- Source: https://en.wikipedia.org/wiki/Sprut_anti-tank_gun and https://en.wikipedia.org/wiki/125_mm_smoothbore_ammunition
- Year: 1989
- Sysmass: the gun is about 6600 kg, towed by MT-LB APC; weight 11900; assume 1000 kg crew and ammo, for a total of 19600 kg
- HP: 240
- Crew: 7
- Offroad speed: 25 kph towed by a MT-LB
- Protection: rifle fire
- Projmass: assume 3BM44 “Mango” that entered service in 1986, projectile weight (without sabot) 4.85 kg

- Velocity: 1715 mps; muzzle energy 7.1 mJ
- Rate of fire: 7
- Effrange: 2000 m (APFSDS)

MFS112:

- System: 2S25 Sprut-SD
- Source: https://en.wikipedia.org/wiki/2S25_Sprut-SD and https://en.wikipedia.org/wiki/125_mm_smoothbore_ammunition
- Year: 2005
- Sysmass: 18000
- HP: 510
- Crew: 3
- Offroad speed: 45 kph
- Protection: “The frontal armor provides protection against attack from 23 mm weapons at 500 m”; corresponds to a 0.190-kg projectile at 970 mps (see https://en.wikipedia.org/wiki/ZU-23-2)
- Projmass: assume 3VBM23/3BM60 (3BM60 "Svinets-2"), projectile weight (without sabot) 8.1 kg
- Velocity: 1650 mps; muzzle energy 12 mJ
- Rate of fire: 7
- Effrange: 2000 m (APFSDS)

MFS113:

- System: 3.7 cm TAK 1918
- Source: https://en.wikipedia.org/wiki/3.7_cm_TAK_1918
- Year: 1918
- Sysmass: 463 kg gun (assume with limber and ammo), plus a horse and seven crew; total 1563 kg
- HP: 1.7
- Crew: 7
- Offroad speed: 5 kph

- Protection: none
- Projmass: 0.465 kg
- Velocity: 435 mps
- Rate of fire: assume 10
- Effrange: 300 m

MFS114:

- System: T-14 Armata tank
- Sources:
    - https://janes.ihs.com/ArmouredFightingVehicles/Display/jafv0063-jafv
    - https://en.wikipedia.org/wiki/Armata_Universal_Combat_Platform
    - https://en.wikipedia.org/wiki/T-14_Armata
- Year: 2017
- Sysmass: 48000
- HP: 1500
- Crew: 3
- Offroad speed: 45 kph (assume comparable to Sprut-SD)
- Protection: assume adequate against 3VBM23/3BM60 (3BM60 "Svinets-2"), projectile weight (without sabot) 8.1 kg; MV=1650; Muzzle energy 12 mJ
- Projmass: assume Vacuum-1 APFSDS round https://en.wikipedia.org/wiki/125_mm_smoothbore_ammunition#3VBM?/3BM69_"Vacuum-1" with 11 kg at 2050 mps (23 KJ)
- Alternatively, compare to recent claims of https://en.wikipedia.org/wiki/Rheinmetall_Rh-120 rounds, assume 8.35 kg with 1800 mps (13 KJ)
- Velocity: see above
- Rate of fire: 10
- Effrange: 3000 m

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MFS118: From Lewtas et al. (2016):

Depending on the century's prevalent composition of black powder, the muzzle velocity was calculated ranging from 231 to 425 mps. Most likely was 315 mps.

MFS124:

- System: Prussian 6-pounder field cannon C/61; this is one of the first (possibly the first) cast-steel breech loader.
- Source: https://de.m.wikipedia.org/wiki/6-Pfünder-Feldkanone_C/61
- Year: 1857
- Sysmass: 1700-kg fully equipped gun (including carriage and limber). Add six horses (assumed) and eight gunners (assumed): total 5500 kg
- HP: 6 horses
- Crew: 8, assumed
- Offroad speed: 5 km/h
- Protection: none
- Projmass: 6.75 kg
- Velocity: 331 m/s
- Rate of fire: Assume 3. Similar Krupp cannons are all listed with 2 rounds per min. However, a later C/73 is listed with 10 rpm in http://www.wikiwand.com/en/8_cm_Kanone_C/73 and https://en.wikipedia.org/wiki/8_cm_Kanone_C/73
- Effrange: 1500 m

MFS124a:

- System: Prussian 6-pounder field cannon C/61 (HA)
- Source: https://de.m.wikipedia.org/wiki/6-Pfünder-Feldkanone_C/61
- Year: 1857
- Sysmass: 5500 kg plus 5000 kg extra horses and 180 kg extra crew
- HP: 17
- Crew: 10
- Offroad speed: 15 km/h

- Protection: none
- Projmass: 6.75 kg
- Velocity: 331 m/s
- Rate of fire: Assume 3. Similar Krupp cannons are all listed with 2 rounds per min. However, a later C/73 is listed with 10 rpm in http://www.wikiwand.com/en/8_cm_Kanone_C/73 and https://en.wikipedia.org/wiki/8_cm_Kanone_C/73
- Effrange: 1500 m

MFS125:

I assume that heavy muskets of 16th century, such as "heavy musket, rifled G284" and "heavy musket, rifled G358" in our database, required an assistant to carry the weapon and the ammunition; therefore, the correct size of crew is two.

MFS126:

- System: Typical Regimental Gun of mid-1600s
- Sources: MFS052, p. 75; MFS056;
  - https://en.wikipedia.org/wiki/Leather_cannon
  - https://en.wikipedia.org/wiki/Infantry_support_gun
- Year: 1650
- Projmass: 3 lb
- Velocity: 300 mps (assume a lower end of the range typical for firearms of the period; see Note MFS057)
- Effrange: 200 m
- Rate: 2
- Protection: none
- HP: 1.3
- Crew: 3
- Sysmass: 620 lb (the barrel and carriage; 280 kg), horse 500 kg, crew 270 kg, ammunition 100 kg; total 1150 kg

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MFS127:

- System: early-to-mid-1600s falcon
- Sources:
    - Note MFS052, p92
    - Norris (2011, p. 62)
    - Note MFS057
- Year: 1625
- Projmass: 3 lb
- Velocity: 300 mps (assume a lower end of the range typical for firearms of the period; see Note MFS057)
- Effrange: 400 yd
- Rate: 1
- Protection: none
- HP: 4.6
- Crew: 6, assumed
- Sysmass: barrel was 800 lb; assume that carriage and equivalent of limber was about 1.5 times the barrel (compare to Gribeauval guns), about 900 kg, plus at least 100 kg for ammunition; add four horses and crew of six; total 3540 kg

MFS128:

- System: early-to-mid-1600s minion
- Sources:
    - Note MFS052, p. 92
    - Norris (2011, p. 62)
    - Note MFS057
- Year: 1625
- Projmass: 6 lb
- Velocity: 300 mps (assume a lower end of the range typical for firearms of the period; see Note MFS057)

- Effrange: 450 yd
- Rate: 1
- Protection: none
- HP: 7
- Crew: 10, assumed
- Sysmass: barrel was 1000 lb; assume that carriage and equivalent of limber was about 1.5 times the barrel (compare to Gribeauval guns), about 1130 kg, plus at least 150 kg for ammunition; add 6 horses and crew of 10; total 5180 kg

MFS129:

- System: early-to-mid-1600s saker
- Sources:
    - Notes MFS052, p. 92, and MFS057
    - Norris (2011, p. 63)
- Year: 1625
- Projmass: 9 lb
- Velocity: 300 mps (assume a lower end of the range typical for firearms of the period; see Note MFS057)
- Effrange: 500 yd
- Rate: 1
- Protection: none
- HP: 9.2
- Crew: 12, assumed
- Sysmass: barrel was 1600 lb; assume that carriage and equivalent of limber was about 1.5 times the barrel (compare to Gribeauval guns), about 1810 kg, plus at least 250 kg for ammunition; add 8 horses and crew of 12; total 7140 kg

MFS130:

- System: mid-1700 cannon, pre-Gribeauval, Austrian 12-pounder

- Sources:
  - Notes MFS052, p. 110, and MFS057, p. 153
- Year: 1740
- Projmass: 12 lb
- Velocity: 344–437 (per Note MFS057, p. 137)
- Effrange: 600 yd
- Rate: 2
- Protection: none
- HP: required 10 horses (vs. Gribeauval' 12-pounder that required 6); total 11.5 hp
- Crew: 15 (assume same as 12-pounder Gribeauval)
- Sysmass: assume 300 kg per horse (i.e., 3000 kg for the barrel, carriage, and limber with ready ammunition); plus 5000 kg horses; plus 15 × 90 kg crew. Total 9350 kg.

MFS131:

- System: British 1805 9-pounder
- Sources:
  - Notes MFS052, p. 120, and MFS122
  - Summerfield (2014)
- Year: 1805
- Projmass: 9 lb
- Velocity: 440 mps (estimated per MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 800 m (Note MFS122)
- Rate: 2
- Protection: none
- HP: 7.2 (6 horses and 12 crew)
- Crew: 12 (10–13 were typical for a 6- and 12-pounder, respectively)

- Sysmass: barrel, carriage, and limber are reported as 1920 kg; 3000 kg horses and 12 × 90 kg crew; 200 kg ready ammunition. Total 6200 kg

MFS131a:

- System: British 1805 9-pounder (HA)
- Sources:
  - Notes MFS052, p. 120, and MFS122
  - Summerfield (2014); see Note MFS096
- Year: 1805
- Projmass: 9 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 800 m (Note MFS122)
- Rate: 2
- Protection: none
- HP: 17.4
- Crew: 14
- Sysmass: 6200 kg plus 5000 kg extra horses and 180 kg extra crew; total 11380 kg

MFS132:

- System: British 1790 Medium 12-pounder
- Sources:
  - Notes MFS052, p. 120, and MFS122
  - Summerfield (2014)
- Year: 1790
- Projmass: 12 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder—440-460 mps)
- Effrange: 900 m (Note MFS122; add 100 m for heavier caliber)

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- Rate: 2
- Protection: none
- HP: 7.3 (6 horses and 13 crew)
- Crew: 13 (10–13 were typical for 6- and 12-pounder, respectively)
- Sysmass: barrel, carriage and limber are reported as 2244 kg; 3000 kg horses and 13 × 90 kg crew; 300 kg ready ammunition. Total 6714 kg

MFS132a:

- System: British 1790 Medium 12-pounder (HA)
- Sources:
    - Notes MFS052, p. 120, MFS122, and MFS096
    - Summerfield (2014)
- Year: 1790
- Projmass: 12 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 900 m (Note MFS122; add 100 m for heavier caliber)
- Rate: 2
- Protection: none
- HP: 17.5
- Crew: 15
- Sysmass: 6714 kg plus 5000 kg extra horses and 180 kg extra crew; total 11894 kg
- Offroad speed: 15

MFS133:

- System: French AnXI 12-pounder
- Sources:
    - Notes MFS052, p. 120, and MFS122
    - Summerfield (2014)

- Year: 1808
- Projmass: 12 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 900 m (Note MFS122; add 100 m for heavier caliber)
- Rate: 2
- Protection: none
- HP: 7.3 (6 horses and 13 crew)
- Crew: 13 (10–13 were typical for 6- and 12-pounder, respectively)
- Sysmass: barrel, carriage and limber are reported as 1867 kg; 3000 kg horses and 13 × 90 kg crew; 300 kg ready ammunition. Total 6337 kg

MFS133a:

- System: French AnXI 12-pdr (HA)
- Sources:
    - Notes MFS052, p. 120, and MFS122
    - Summerfield (2014)
- Year: 1808
- Projmass: 12 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 900 m (Note MFS122; add 100 m for heavier caliber)
- Rate: 2
- Protection: none
- HP: 17.5
- Crew: 15
- Sysmass: 6337 kg plus 5000 kg extra horses and 180 kg extra crew; total 11517 kg
- Offroad speed: 15

MFS134:

- System: French AnXI 6-pdr
- Sources:
  - Notes MFS052, p. 120, and MFS122
  - Summerfield (2014)
- Year: 1808
- Projmass: 6 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil war American: 6- and 12-pounder, 440–460 mps)
- Effrange: 700 m (Note MFS122; reduce by 100 m for lighter caliber)
- Rate: 2
- Protection: none
- HP: 5 (4 horses and 10 crew)
- Crew: 10 (10–13 were typical for a 6- and 12-pounder, respectively)
- Sysmass: barrel, carriage and limber are reported as 1350 kg; 2000 kg horses and 10 × 90 kg crew; 150 kg ready ammunition. Total 4400 kg

MFS134a:

- System: French AnXI 6-pounder (HA)
- Sources:
  - Notes MFS052, p. 120, MFS122, and MFS096
  - Summerfield (2014)
- Year: 1808
- Projmass: 6 lb
- Velocity: 440 mps (estimated per Note MFS057, p. 137: Late 18th century: 344–437 mps; Civil War American: 6- and 12-pounder, 440–460 mps)
- Effrange: 700 m (Note MFS122; reduce by 100 m for lighter caliber)
- Rate: 2
- Protection: none

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- HP: 15.2
- Crew: 12
- Sysmass: 4400 kg plus 5000 kg extra horses and 180 kg extra crew; total 9580 kg
- Offroad speed: 15

MFS135:

- System: Griffen 3-inch Ordnance Rifle
- Sources:
    - o Note MFS052, p. 149
    - o Welsh (2018)
- Year: 1854
- Projmass: Ordnance shell was 7.5 lb, case and canister were 10.5 and 10 lb; 6 lb shot
- Velocity: assume 460 (see Note MFS057, p. 137)
- Effrange: 1800 m
- Rate: 2
- Protection: none
- HP: 4.8 (4 horses and 6 crew)
- Crew: 8 (assumption)
- Sysmass: barrel weight 830 lb, assume that the total of barrel, carriage and limber was 3.5 of barrel (similar to the AnXI 6-pounder), which is 1316 kg; requires four horses of 2000 kg; 200 kg ready ammunition and 8 × 90 kg crew. Total 4236 kg

MFS135a:

- System: Griffen 3-inch Ordnance Rifle (HA)
- Sources:
    - o Notes MFS096 and MFS052, p. 149
    - o Welsh (2018)
- Year: 1854

Approved for public release; distribution is unlimited.

- Projmass: Ordnance shell was 7.5 lb, case and canister were 10.5 and 10 lb; 6 lb shot
- Velocity: assume 460 (see Note MFS057, p. 137)
- Effrange: 1800 m
- Rate: 2
- Protection: none
- HP: 15
- Crew: 10
- Sysmass: 4236 kg plus 5000 kg extra horses and 180 kg extra crew; total 9416 kg

MFS136:

- System: A7V tank;
- Sources:
    - https://en.wikipedia.org/wiki/A7V
    - Macksey (1988, pp. 38–41)
- Year: 1917
- Projmass: 2.7 kg
- Velocity: 401 mps
- Effrange: 1500 m (assume same as the Mark IV)
- Rate: 25
- Protection: 300-m armor, possibly adequate against FT17: 120600 J
- HP: 200
- Crew: 18
- Sysmass: 33000
- Offroad speed: 5 kph

MFS137:

- System: Leopard 2A6M

- Sources:
    - o https://janes.ihs.com/Janes/DisplayFile/JAA_0021#Leopard%202A6
    - o https://en.wikipedia.org/wiki/Leopard_2
    - o https://en.wikipedia.org/wiki/Rheinmetall_Rh-120
- Year: 2007
- Projmass: 8.35 kg. Alternatively, see Note MFS095a, assume comparable to the Soviet 3BM69, claimed 11 kg.
- Velocity: 1750 mps. Alternatively, see Note MFS095a, assume comparable to the Soviet 3BM69, claimed 2050 mps.
- Effrange: 4000 m
- Rate: 8 (assume the same as the M1A1 Abrams)
- Protection: 11000000 (assume the same as the M1A1 Abrams)
- HP: 1479
- Crew: 4
- Sysmass: 62500
- Offroad speed: 35 kph (assume half of road speed 69 kph)

MFS138:

- System: Swedish Strv 103B (aka S Tank)
- Source: https://en.wikipedia.org/wiki/Stridsvagn_103
- Year: 1971
- Projmass: the gun is a longer version of the British Royal Ordnance L7 series gun; 7.6 kg (assume same as the Chieftain tank)
- Velocity: 1370 mps (assume same as the Chieftain tank)
- Effrange: 3000 m (assume same as the Chieftain tank)
- Rate: 15 (with autoloader)
- Protection: assume comparable with T-54/55. ME 7,800,000
- HP: 490

- Crew: 3
- Sysmass: 39700
- Offroad speed: 30 kph (assume comparable to other tanks of early 1970s)

MFS139:

- System: Challenger 2 tank
- Sources: https://en.wikipedia.org/wiki/Challenger_2; see notes on Challenger 1
- Year: 1989
- Projmass: See note MFS095a. Assume comparable to the Soviet 3BM44, 4.85 kg.
- Velocity: 1715 mps
- Effrange: 4000 m (comparable with other tanks of the period)
- Rate: 10
- Protection: assume compatible with tank guns of the period, about 12 mJ
- HP: 1200
- Crew: 4
- Sysmass: 75000
- Offroad speed: 40 kph

MFS140:

- System: 47-mm APX antitank gun
- Source: https://en.wikipedia.org/wiki/47_mm_APX_anti-tank_gun
- Towed perhaps by https://en.wikipedia.org/wiki/Lorraine_37L or the lighter https://en.wikipedia.org/wiki/Renault_UE_Chenillette
- Year: 1936
- Projmass: 1.7 kg
- Velocity: 855 mps
- Effrange: 550 m
- Rate: 17

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- Protection: 3000
- HP: 38
- Crew: 6
- Sysmass: gun itself 1070 kg, UE Chenillette was 2640 kg, with 38 hp; 6 crew were 540 kg, ammunition 200 kg; total: 4450 kg
- Offroad speed: assume 15 kph, half of UE road speed of 30 kph

MFS141:

- System: 3.7-cm Pak 36 antitank gun
- Source: https://en.wikipedia.org/wiki/3.7_cm_Pak_36
- Year: 1933
- Projmass: 0.685 kg
- Velocity: 745 mps
- Effrange: 500 m
- Rate: 13
- Protection: 3000
- HP: 38; assume UE Chenillette as the artillery tractor (widely used by the German artillery in WW2); see Note MFS140.
- Crew: 5
- Sysmass: gun in combat configuration 327 kg, add 150 kg ammunition, 450 kg crew, 2640 kg tractor; total: 3567 kg
- Offroad speed: 15 kph

MFS143:

- System: 5-cm Pak 38 (L/60) antitank gun
- Source: https://en.wikipedia.org/wiki/5_cm_Pak_38
- Year: 1940
- Projmass: 2.25 kg
- Velocity: 1130 mps
- Effrange: 1500 m

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- Rate: 13
- Protection: 3000
- HP: 38
- Crew: 5
- Sysmass: the gun was 830 kg; assume it was towed by UE Chenillette (see Note MSF141); add 250 kg ammunition, 450 kg crew, 2640 kg tractor; total: 4170 kg
- Offroad speed: 15 kph

MFS144: From Halberstadt (2002):

For each artillery piece (towed and self-propelled [SP]), I provide caliber, weight (it does not state however whether that weight includes carriage), effective range (usually higher than other sources), muzzle velocity (not always), but no projectile mass. Here are some excerpts:

p. 20: Light 6-pounder, year 1776, caliber 93 mm, weight 262 kg [*Data compiler's note: possibly barrel only?],* effrange 1050 m [*Data compiler's note: I assume to add 150% of barrel weight, 2000 kg for 4 horses (see Notes MFS147, p. 169, and MFS096), 900 kg for 10 crew, total 3555 kg*].

p. 26: union 6-pounder, 93 mm, 398 kg (including limber, presumably), effrange 1395 m. Typical muzzle velocity for Napoleons was 457 m/s.

p. 27: Parrott rifles 10-pounder, effrange was 1800; 20-pounder 3960 m.

p. 46: French 75-mm 1897, weight 1160 kg, MV 529 m/s.

p. 51: German 77-mm Field Gun M96nA: 77 mm, weight 925 kg, effrange 7800 m, MV 465 m/s.

p. 52: German 105-mm M1917: 105 mm, 3200 kg, effrange 14100 m, MV 650 m/s.

p55: British QF 18-pounder, 84 mm, 1285 kg, effrange 8700, mv 492 m/s.

p. 59: British QF 13-pounder, 76 mm, 1014 kg, effrange 5395 m, mv 510 m/s.

p. 62: French 105-mm Schneider Mle 1913; 105 mm, 2300 kg, effrange 12700 m, mv 550 m/s.

p. 63: Russian M1902 76-mm gun: 76 mm, 1040 kg, effrange 6400 m, mv 593 m/s.

p. 85: German PaK 40: 75 mm, 1425 kg, effrange 2000 m, mv 990 m/s.

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p. 87: FlaK 18 “88”: 88 mm, 25000 kg (with or without vehicle?); effrange 14815, mv 820 m/s. [*Data compiler’s note: data look questionable.*]

p. 110: SU-152: 152 mm, 45500 kg, effrange 17265 m, mv 655 m/s.

MFS145:

Bonsall (2007) describes findings pertaining to a Saker cannon. Ball 2.4 kg, 82 mm diameter, point blank range 518 m, 635–725 kg weight [*Data compiler’s note: assume barrel only*], 6 horses to pull. [*Data compilers’ note: Assume the weight of gun, ready ammo and cart of 1800 kg, based on 300 kg per horse; 3000 kg horses; crew of 10 – 900 kg; total 5700 kg.*]

MFS146:

Allsop and Foard (2007) suggest that in the early modern period, a cannon muzzle velocity was comparable to the contemporary musket muzzle velocity.

MFS148: From Bailey (2004):

p. 148: In 1450, French culverins could fire 17-lb ball accurately to 400 m.

p. 151: In late 1700s, maximum effective range for a light gun was about 1000 m, and of heavier pieces, 1500 m

p. 152: Late 1700s, a shot from a 8- or 9-pounder at 0° elevation would strike the ground at 400 m, ricochet and bounce at 600 m, then at 700 m. A shot from 4- or 6-pounder would first hit the ground at 300 m. A shot of 12-pounder, at 600 m. Guns were seldom elevated, else the trajectory was above the head level.

p. 156: As late as 1854, 70% of all cannon fire was solid shot.

p. 167: Gribeauval guns, in 1750–1760s, the weight of a French 4-pounder fell from 1300 lb to 600 lb, it could be drawn by just three horses and handled by eight men.

p. 169: Mid-1700s, Prussian 6-pounder was drawn by five horses and was considered relatively immobile.

p. 175: Little technical innovation between 1700 and 1800; the range of a 12-pounder cannon the same as in 1700.

p. 182: Light guns could fire 2–3 rounds at the cyclical rate of 8–9 rpm, but could only fire 2–3 to prevent overheating. Horse artillery would first unlimber and fire at 800 m.

p. 189: The French in 1859 demonstrated higher range and accuracy with rifled cannon using de Beaulieu system proposed in 1842.

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p. 189: The 3-inch Parrot gun of early 1860s could throw a 10-lb shell 3200 m, but the target could not be seen at that distance. Was expected to hit a target at 1500 m on the fourth shot.

p. 190: Napoleon gun entered French service in 1857, range of 1600 m was about same as 50 years earlier, but weight was one-third less.

p. 207: Before 1860, artillery caused 50% of battle casualties, for the next 50 years—only 5%–15%. Rifles became more lethal. Armored shields for field guns were introduced between 1869 and 1914.

p. 217: In 1870 German counterbattery fire started at 2–3 km; rifled breech-loaders. Stopped infantry advance at 2000 m. Mitrailleuse fired 150 rounds per minute, up to 2000 m.

p. 523: An Abrams tank gun produces 18–20 MJ muzzle energy.

MFS150

Anonymous (1890) mentions muzzle velocity of 1809 fps in connection with Parrott-style guns of Civil War period. The weight was 890 lb [*Data compiler's note: probably barrel only.*] for the 10-pounder.

6. Conclusions

To my knowledge, the data sets presented in this report are the first of their kind and are not directly available elsewhere.

Much future work can be recommended with respect to these data sets. Additional classes of weapon systems should be added. Greater completeness of coverage should be pursued even for those classes that are already considered in the data sets. Additional sources should be sought to improve the accuracy and credibility of the data. Researchers who use these data sets should proceed with caution, recognize that individual data points could be inaccurate, and cross-validate the results.

Nevertheless, although limited and imperfect in many respects, these data sets can be used for exploratory studies of quantitative trends in military technologies of the period from about 1000 CE to the present.

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List of Symbols, Abbreviations, and Acronyms

AP	armor-piercing
CCDC ARL	Combat Capabilities Development Center Army Research Laboratory
CE	Common Era
DOD	Department of Defense
effrange	effective range
FoM	figure of merit
HAI	heavy armored infantry
HA	horse artillery
KE	kinetic energy
LAI	light armored infantry
LNI	light infantry without armor
m	mass
MAI	modern infantry that uses body armor
ME	muzzle kinetic energy
MFS	ground-mobile, direct-fire systems
MV	muzzle velocity
NATO	North Atlantic Treaty Organization
SP	self-propelled
V	velocity

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