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Use of Explosive Weapons in Populated Areas (EWIPA)

Submission by Germany

1. This Working Paper is meant to substantiate the debate of the High Contracting Parties but does not intend to reflect the German position.

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Introduction

The use of explosive weapons in populated areas has caused high numbers of casualties among the civilian population in many war-torn countries in recent years. In addition, the destruction of houses, hospitals, schools, bakeries, stores and ware houses, communications, power plants, dwells and drainage systems often lead to the collapse of the public health system, shortage of food, water and energy supply, and the degradation of the education. Humanitarian disaster, displacement of people and mass migration are the consequences associated with high cost for national and international communities to organize humanitarian relief operations, emergency supply, provisional housing, rehabilitation of people and rebuilding destroyed structures. Explosive remnants of war could cause losses long after the war has ended.

Most severe cases like the bombardments of cities in Syria (Aleppo, Ar-Raqqah), Iraq (Mosul), the Gaza strip, Yemen, Libya, Afghanistan and Ukraine (Donetsk, Mariupol) have raised the awareness of the international community and led governments and NGOs to consider action in order to diminish the effects of the use of explosive weapons in populated areas.

In the current public discourse, the focus is on the weapons in use rather than on the political intentions and military objectives, doctrines and capabilities of involved actors and their willingness or ability to comply with international humanitarian law and human rights law. However, also quality criteria such as the professionality, cohesiveness, discipline and interoperability of different armed formations, military leadership skills, in particular the ability to carry out coordinated combined arms operations, training, intelligence, and the availability of appropriate munitions and accurate targeting technologies, merit deeper consideration.

Against this backdrop, this paper is to analyse the following questions:

- Which types of attacks and munitions cause high numbers of civilian casualties?
- What are the patterns of conflicts in which civilians have become subject to indiscriminate or disproportional warfare and which actors are involved?
- Which weapon systems, munitions and targeting techniques do they typically use?
- What is the rationale for military operations in populated areas? To what extent can they be avoided or curbed weighing proportionality of military necessities and protection of civilians?
- Which practical measures could be taken to better protect the civilian population in zones of armed conflict?

Executive Summary

High civilian casualties resulting from the use of explosive munitions in populated areas give reason for concern. While the recorded numbers are incomplete and, in some instances, their plausibility might have to be re-examined, they generally point at a trend towards disproportional or indiscriminate warfare in contemporary wars.

There seems to be an urgent need for states to discuss how such trends can be reversed and which measures could be taken to strengthen compliance with International Humanitarian Law. Best practices or codes of conduct as to the design of rules of engagement (ROEs) could be considered in order to curtail the area effects of explosive weapons in populated areas.

Available records on civilian casualties distinguish between air-launched, ground-launched and IED-attacks. IED attacks account for more than half of all civilian deaths and injuries between 2011 and 2016 while ground-launched attacks have caused 22 % and air-launched attacks 18 % of civilian casualties though the latter rose to 31 % in 2016. IED attacks were carried out exclusively and ground-launched attacks mainly by non-state actors; air attacks were launched exclusively by state actors.

Most of the IED-attacks were terrorist actions deliberately targeting civilians not only in countries affected by internal unrest or armed conflict but also in states that live in peace. However, such deliberate killing of civilians by terrorists does not fall in the category of indiscriminate or disproportional warfare and requires different approaches by states.

The vast majority of recorded cases in which civilians became victims of the use of explosive munitions occurred in context with internal unrest, civil war and non-international armed conflict. Under such conditions, ground attacks are carried out mainly by increasingly disorganized government forces and irregular armed formations that lack the military capabilities necessary for precise use of munitions and accurate targeting. They often resort to asymmetric hit and run-tactics or indiscriminate area fire to cause attrition of enemy forces.

In contrast, intervening states use superior air forces to turn the balance and reverse rebel momentum. However, the increasing civilian casualties resulting from obviously disproportionate air attacks in 2016 are a matter of concern. Also the use of advanced precise munitions and accurate targeting methods often results in civilian casualties.

The fact that almost 60 % of all recorded civilian casualties were caused by non-state actors raises the question how tighter restrictions for operations of state armed forces in populated areas could curtail those of non-state actors and how states should tackle this problem.

The patterns of asymmetric warfare with its tendency towards disproportional and indiscriminate warfare should be taken into consideration. Arms deliveries and logistical supply of regular and irregular forces involved in internal, non-international armed conflict prolong the war and the suffering of civilians, particularly, as deteriorating equipment, professional skills and moral standards lead to excessive use of explosive munitions. Therefore, politics should be revised that grant military support to armed actors involved in internal wars.
Most of the ground- and air-launched munitions in use by armed forces and irregular armed groups – except for kinetic energy canon rounds and small arms – carry high explosives to achieve military purposes such as penetrating and destroying armoured targets and hardened objects or covering wider areas where mass targets are dispersed or single targets cannot be located exactly.

All detonations of explosive weapons cause blast, heat and high-speed dispersion of fragments within a circle around the point of impact. Such area effects occur irrespective of the question whether the projectile or warhead hits precisely the aim point. The lethal and incapacitating area around the point of impact depends mainly on the yield, the composition of high explosives and fragments, and the setting of fuses.

Inherent imprecision of delivery systems, various types and production lots of munitions, charges and fuses, as well as environmental conditions influence trajectories of projectiles or rockets and times of detonation leading to variations in the points of impact. Such imprecisions are typical for indirect fire weapon systems and increase with range. They cause – often significant – deviations of the point of impact from the aim point resulting in enlarged lethal and incapacitating areas. Direct fire weapon systems can reach a much higher degree of precision. However, area effects can be militarily intended to engage mass targets simultaneously.

Inaccuracies of targeting processes, firing procedures and communication can multiply the technical imprecision of indirect fire delivery systems and munitions. Professional armies enhance the reliability of weapon systems and munitions by thorough life-firing testing, assessment of data and translation into field manuals while the performance of crews is improved by intensive training. In contrast, in contemporary non-international wars, regular and irregular ground forces use elder armaments and targeting equipment with low technical performance and professional skills due to the lack of training and adequate doctrines.

Advanced guided munitions can greatly enhance the precision of delivery and, thus, allow for smaller yields and reduced area effects when directed against single point targets. Modern target acquisition sensors and fire control systems improve the accuracy of delivery and the reaction time. In particular, sustained area surveillance can assure that the selection and delivery of munitions respond to the actual situation in the target area.

However, unclear and rapidly changing battlefield conditions with enemy counter-measures, quick target movements and fluid combat situations can result in insufficient intelligence and target reconnaissance, disruption of communications and delays of weapon delivery in the targeted area. That can lead to false situation assessments, failures of targeting and unintended collateral damage even if highly precise weapon systems are used.

The military necessity of using explosive weapons in populated areas depends on different needs in different scenarios. Asymmetric scenarios would not be typical for international armed conflicts between states with advanced military capabilities. Therefore, they do not allow for far-reaching conclusions as to military operations under different conditions.

Consequently, the question to what extent the use of explosive weapons in populated areas can be avoided and what could be done to reduce its effects on the civilian population cannot be answered by one set of generally applying responses.
In case of a full-fledged attack against the national sovereignty and integrity of densely populated countries like Germany the renunciation of the use of explosive weapons would make any effective defence impossible. In such a national defence scenario, large-scale, geographically extended operations with mass targets would dominate the battlefield and vital national interests were at stake. In consequence, military operations would require different rules of engagement (ROEs) compared to stabilizing operations in a low-intensity, asymmetrical scenario and the interpretation of proportionality requirements might differ. That is particularly true in centres of gravity where the fluid, complex and unclear situation diminishes the ability to achieve precision while the military objectives have to be fulfilled. Civil protection and evacuation might have to be considered.

Also in low-intensity scenarios where troops have to carry out stabilizing operations a total renunciation of the use of explosive weapons is no option if enemy fighters should not be granted military advantages and own forces exposed to indirect and direct enemy fire. However, such use should be subject to tight restrictions as to the selection and use of delivery means and munitions and the geographical choice of battle spaces in order to protect civilians.

Any such use must be prepared by thorough intelligence, target reconnaissance, target acquisition and continuous surveillance of the target area up to the weapons' delivery and beyond. Before the employment, a collateral damage estimate should be made for every option of a potential use of explosive weapons taking into account the situation of the civilian population. Such estimate should guide the choice of appropriate weapon systems, munitions and fuses and ensure high precision and low yields to curtail area effects.

Continuous surveillance of the target area is necessary to enable last minute decisions and to ensure that laser illumination and other precise guiding methods function uninterrupted during the whole targeting and delivery process. Up to the end of the operation, safety distances for friendly troops should inform appropriate safety distances also for civilians. Commanders should issue an appropriate warning to the civilian population. The delivery should be delayed or cancelled if civilians move too close to the target area and the military purpose can be achieved by alternative operations. However, proportional self-defence of own troops must remain possible.

Such rules should be enshrined in field manuals and rules of engagement (ROE) and troops educated and trained accordingly. International Humanitarian Law (IHL) also requires States to determine whether the employment of a new weapon, means or method of warfare would, in some or all circumstances, be prohibited. Therefore, new systems must be designed and tested thoroughly, reliable data bases be established and the findings translated into field manuals and training instructions. Incidents that could involve serious violations of IHL should be recorded, in particular, if they are severe and repetitive and point at a general degradation of compliance and morale.

Despite the revolutionary development in precision and accuracy of delivery means and munitions, any believe in the possibility of conducting a "clean war" is flawed. In particular in high intensity scenarios, frictions at all levels and steps of target reconnaissance, target acquisition and location, targeting processes and weapon delivery will be the rule and no exception. War prevention is a more realistic concept. It includes confidence- and security-building measures and arms control that curtails military options and potentials for offensive operations.

Part I

Statistics: Civilian Casualties caused by the Use of Explosive Weapons

1.1 Numbers of civilian casualties and types of attacks

1.1.1 Global statistics

The "Action on Armed Violence" (AOAV) recorded in 2016 2,300 incidents globally in which 45,624 deaths and injuries were caused by explosive weapons. Of these, 70 % were civilians, i.e. 32,088, as opposed to 13,536 armed actors, representing 30 % of overall casualties.[1]

[1] Cf. Jennifer Dathan, Action on Armed Violence (AOAV): Explosive Truths. Monitoring explosive violence in 2016. April 2017, p. 3 (The AOAV is operating from UK and funded by the Government of Norway.)

According to AOAV, 1,241 attacks (54 % of all recorded attacks) took place in populated areas in which 92 % of the casualties were civilians, i.e. 28,493 (representing 89 % of overall civilian casualties). In contrast, 1,059 attacks were carried out in non-populated areas in which only 25 % of the casualties were civilians.[2] AOAV recorded an average of 23 civilian casualties per incident of explosive weapons use in populated areas, compared to 3 in other areas.[3] I.e., in non-populated areas approximately 10,900 casualties among combatants outnumbered 3,600 civilian casualties while in populated areas approximately 2,600 casualties were reported among combatants as opposed to 28,500 civilian casualties.

In 338 incidents, 1,490 child deaths or injuries were recorded in 2016.[4] 502 women were reported killed or injured in 251 incidents. Since that includes 50 incidents in which no detailed figure was given, the actual number of female casualties might be higher.[5]

Housing areas as well as commercial and religious centres suffered particularly high numbers of civilian casualties: [6]

	Incidents	*Total casualties*	*Civilian casualties*	*Average civilian casualties per attack*
Urban residential areas	368	5,865	5,741 (98 %)	16
Markets	78	2,793	2,733 (98 %)	35
Places of worship		1,719	*1,667*[7] (97 %)	43

1.1.2 Types of attacks

According to the AOAV report, civilian casualties due to the use of explosive weapons were caused by the following weapon launch methods (*deduced approximate figures in italics*):[8]

Types of attacks (% of all civilian casualties)	*recorded incidents*	*total casualties*	*of which combatants (%)*	*civilians (%)*	*average per attack*
Air-launched[9] (31 %)	679	16,490	6,556 (40 %)	9,934 (60 %)	15
- in non-populated areas	(367)	54 % *6,830*	*6,036* (87 %)	*794* (13 %)	2
- in populated areas (32 %)	(312)	46 % *9,660*	*520* (5 %)	*9,140* (95 %)	29
Ground-launched[10] (22 %)	*664*	8,849	1,852 (21 %)	6,997 (79 %)	10
- in non-populated areas	(*246*) 37 %	*2,949*	*1,588* (54 %)	1,361 (46 %)	6
- in populated areas (20 %)	(*418*) 63 %	*5,900*	*264* (4 %)	5,636 (96 %)	13

[2] Loc. cit., p. 5, 6
[3] Loc. cit., p. 17
[4] Loc. cit., p. 17, 20
[5] Loc. cit., p. 20
[6] Loc. cit., p. 5, 6, 17, 19; by comparison, on markets only 60 armed actors were killed or injured. Loc. cit., p. 19
[7] Figure deduced from percentage given on p. 5
[8] Loc. cit., p. 6, 21, 22, 23 (Where positive figures were not contained in the report, *approximate figures* were deduced from percentages given by AOAV.)
[9] Loc. cit., p. 3, 21, 28, 30, 31
[10] Loc. cit., p. 30, 31

IED[11] (45 %)	*911*	19,256	4,955 (26 %)	14,301 (74 %)	16
- in non-populated areas	(*419*) 46 %	*4,366*	*3,165* (71 %)	*1,201* (29 %)	3
- in populated areas (46 %)	(492) 54 %	*14,890*	*1,790* (12 %)	*13,100* (88 %)	27
Combined, unknown (2 %)[12]	*46*	*1,029*	*173*	856	18
- in non-populated areas	*27*	*379*	*140*	*239*	
- in populated areas	*19*	650	33	617	
Total[13] (100 %)	2,300	45,624	13,536	32,088 (70 %)	14
- in non-populated areas	1,059 (46 %)	*14*,524	*10,929*	3,595 (25 %)	3
- in populated areas (89%)	1,241 (54%)	*31,100*	*2,607*	28,493 (92 %)	23

679 recorded air-launched attacks in 15 countries caused 9,934 civilian casualties representing 31 % of all civilians killed or injured. 64 % of civilian casualties from air attacks (6,382) occurred in Syria, 23 % in Yemen (2,249) and 10 % in Iraq (almost 1,000). The number of air-launched attacks exceeded those recorded in 2015 by 36 % which mirrors predominantly the increase in air attacks in Syria (+ 77 %) and Iraq while air attacks in Yemen decreased due to a temporary ceasefire. In contrast, the number of civilian casualties resulting from air attacks increased only by 7 % compared to 2015. However, on an average still 60 % of all casualties caused by air-launched attacks were civilians although significant regional differences were observed comparing the high numbers in Syria and Yemen with the lower numbers in Iraq. When air attacks occurred in populated areas (46 % of all air attacks) the numbers of civilian casualties rose to 95 % as opposed to 13 % in non-populated areas. On an average, air dropped bombs caused 21 deaths and injuries per incident.[14]

Some 660 recorded ground-launched attacks in 42 countries caused 6,997 civilian casualties representing 22 % of all civilians killed or injured. 79 % of casualties caused by ground-launched attacks were civilians, 21 % armed actors. In populated areas, the number of civilian casualties rose to 5,636 representing 96 % of casualties hit by ground-launched weapons in such areas while, according to AOAV records, armed actors suffered less than 300 losses.

Some 900 recorded attacks with Improvised Explosive Devices (IED) in 48 countries have caused the highest number of civilian casualties in 2016 with 16 civilian casualties per incident on an average. They alone account for 14,301 civilian casualties representing 45 % of all civilians killed or injured by the use of explosive weapons and 74 % of all casualties (19,246) caused by IED attacks (as opposed to 26 % armed actors, i.e. 4,945).[15] 492 of the IED attacks occurred in populated areas. In particular, the devastating effects of suicide bombings are salient: AOAV counted 256 suicide bombings in 2016 causing a total of 12,673 deaths and injuries of which 9,680 (76 %) were civilians. Although suicide bombings represent only 28 % of all IED attacks they caused 66 % of all casualties from such attacks. Car bombs resulted in 27, and suicide bombings in 38 civilian casualties per incident on an average; in populated areas this figures rose even to 51.[16]

On the list of the ten worst incidents recorded in 2016 an airstrike by the Saudi-led coalition against a public place in Sana'a, Yemen, causing 735 civilian casualties ranked first, followed by six suicide and car bomb attacks in Iraq, Pakistan, Afghanistan, Turkey and Syria, each causing

[11] Loc. cit., p. 23, 31
[12] Loc. cit., p. 6, 22
[13] Loc. cit., p. 2, 3, 5, 9, 10, 13, 17, 18
[14] Loc. cit., p. 22, 28, 29, 30 (note: On p. 6, the report states that the average number of civilian casualties per air dropped bomb amounts to 27.)
[15] Loc. cit., p. 24
[16] Loc. cit., p. 4, 6, 22, 23, 25, 26

between 260 and 520 civilian casualties, and two airstrikes in Syria, one in eastern Aleppo with 385 recorded civilian victims and one attack with “*barrel bombs*” against an ISIS-held village resulting in 303 civilian casualties. An airstrike by the US-led coalition hit a market in ISIS-held area in Iraq in which 300 civilians were killed or injured.[17]

Within these figures AOAV does not distinguish between people killed and those injured. However, it states that in 2016 32 civilians were killed per day.[18] That would amount to a total of 11,680 civilians killed representing 36.4 % of the overall 32,088 civilian casualties. Based on this assumption, approximately 5,200 civilians were killed due to IED attacks (45 %), 3,620 civilian fatalities resulted from air-dropped munitions (31 %) and 2,560 were caused by ground-launched attacks (22%).

According to AOAV records, the explosive violence between 2011 and 2016 resulted in a total of 233,949 deaths and injuries of which 177,653 were counted as civilians (76 %). In populated areas 159,230 civilians were killed or injured representing 91 % of all casualties in such areas while in less populated areas 18,423 civilian casualties were counted representing 31 % of all casualties.[19] 57 % of all civilian casualties were caused by IED attacks, 22 % by ground-launched attacks and 18 % by air attacks which reached an annual maximum in 2016.

Year	2011	2012	2013	2014	2015	2016
Total casualties	30,301	34,689	37,693	41,847	43,795	45,624
Civilian casualties	21,689	27,014	30,893	32,662	33,307	32,088

1.2 Affected countries, patterns of conflict, state and non-state actors

AOAV has recorded 2,300 incidents in 70 countries[20] globally where explosive devices were used. Altogether, civilian casualties were recorded in 7 more countries than in 2015. However, casualties from explosive weapons were also reported in 20 countries that were not affected in 2015. According to AOAV records, IED attacks took place in 48 countries, ground-launched attacks in 42 countries, and air-launched attacks in 15 countries.[21]

Thus, the data collected do not only refer to wars and warlike armed violence during internal unrest but also to states that have remained in a status of peace on national territories but in which terrorist attacks occurred, e.g. in France, Belgium and United Kingdom. In regard of air- and ground-launched attacks it is important to note that their vast majority were launched in the context of internal (“civil”) wars and the fight of governments and international coalitions against terrorist organizations such as ISIS or Al-Qaeda affiliates.

1.2.1 Affected countries

According to AOAV data, armed conflicts in Syria, Iraq, Yemen, Afghanistan, Turkey, Pakistan, Somalia, Nigeria, Cameroon and Libya have caused the highest numbers of casualties resulting from the use of explosive weapons in populated areas in 2016[22]:

Country	recorded	all	of which	
	Incidents	casualties	armed actors (%)	civilian (%)
Syria	553	15,640	2,327 (15 %)	13,313 (85 %)

[17] Loc. cit., p. 9
[18] Loc. cit., p. 10
[19] Loc. cit., p. 33, 34
[20] Loc. cit., p. 10
[21] Loc. cit., p. 4
[22] Loc. cit., p. 12

Aleppo ~ 60 %			*~ 8,000*	
Iraq	401	9,785	3,426 (35 %)	6,359 (65 %)
Yemen	151	4,095	1,382 (34 %)	2,713 (66 %)
Afghanistan	198	4,095	1,896 (46 %)	2,199 (54 %)
Turkey	110	2,675	850 (32 %)	1,825 (68 %)
Pakistan	158	2,136	638 (30 %)	1,498 (70 %)
Somalia	87	1,414	588 (42 %)	826 (58 %)
Nigeria	29	900	409 (45 %)	491 (55 %)
Cameroon	10	337	18 (5 %)	319 (95 %)
Libya	38	782	473 (60 %)	309 (40 %)
Belgium	2	264	3 (2 %)	261 (98 %)
Philippines	48	358	97 (27 %)	261 (73 %)
India	124	458	224 (49 %)	234 (51 %)
Thailand	52	279	103 (37 %)	176 (63 %)
Egypt	65	705	547 (78 %)	158 (22 %)
15 countries	*1,373*	*43,923*	*12,981 (29,6 %)*	*30,942 (70,4 %)*

In five additional countries more than 10 incidents involving the use of explosives in 2016 occurred: Ukraine (53), Saudi Arabia (50), Azerbaijan (17), Burundi (17) and Sudan (12).[23]

Syria

With a total of 15,640 casualties of which 13,313 (85 %) were civilians according to AOAV records, Syria saw the highest number of civilian casualties due to the use of explosive weapons in 2016. That constitutes a 52 % increase from the previous year which is consistent with the surge in air and ground attacks that reached a peak between September and December 2016. Since the beginning of the uprising in 2011, AOAV recorded a total of 51,875 casualties from 2,160 incidents of explosive violence in Syria of which 86 % were civilians (approximately 44,600) according to media reports.[24] Applying an average rate of 36 % fatalities among the recorded casualties (see p. 9) the resulting figure of civilians killed by the use of explosive weapons in Syria since 2011 would be approximately 16,000.

However, AOAV does not claim comprehensive recording and assumes that the overall figures could be higher.[25] (See also section "*attribution*" below.) In light of the sharp increase in air attacks in Syria in 2016 (+77 %) AOAV believes that the above data represent only a fraction of the real casualties which had not been reported, particularly those resulting from the sieges of eastern Aleppo during the last months of 2016.

The recorded 13,313 civilian casualties in 2016 were caused by the following modes of attacks:[26]

	Air-launched attacks	ground-launched attacks	improvised explosive devices (IED)	combination, mines or unknown
percentage	48 %	33 %	14 %	5 %
deduced approx. numbers	*6,385*	*4,393*	*1,865*	*670*
of which killed approx. 36 %	*2,300*	*1,580*	*670*	*240*

[23] Loc. cit., p. 15
[24] Loc. cit. p. 11, 12
[25] Loc. cit., p. 10, 14, 37, 38
[26] Loc. cit., p. 11

In 2016, 60 % of all civilian casualties in Syria were counted in the province and city of Aleppo amounting to about 8,000 killed or injured civilians.[27] 73 % of the 553 incidents recorded in 2016 took place in populated areas, responsible for 89 % of civilian casualties. When explosives were used in populated areas, on an average 97 % of the casualties were civilians. 173 incidents involved direct hits on residential areas, 22 on hospitals and 15 on schools.[28]

AOAV believes that in 2016 55 % of the civilian casualties (approx. 7,300) in Syria were caused by the government of Syria and the Russian air force. No figures were provided on weapons effects resulting from air attacks by the US-led coalition or Turkish and Israeli air forces. Assuming that the losses resulting from air attacks were predominantly caused by the air forces of Syria and Russia, the above figures suggest that ground-launched attacks of Syrian troops were responsible for 7 % of the civilian casualties (approx. 930). In turn, it means that 45 % of civilian losses resulted from attacks carried out by armed rebels and terrorist groups in Syria, amounting to a combined figure of approx. 6,000 civilians killed or injured. Approx. 1,900 were caused by IED-attacks[29] and more than 4,000 by ground attacks.
Two airstrikes and two simultaneous IED attacks in Syria ranked high on the list of worst incidents reported in 2016: one airstrike destroyed residential areas in eastern Aleppo with 385 recorded civilian victims; one air attack with “barrel bombs” against the ISIS-held village of Oqayrabat resulted in 303 reported civilian casualties; a simultaneous car bomb and suicide attack against Shia shrines in Sayyidah Zayrab killed or injured 251 civilians.

Iraq
With 401 incidents and a total of 9,785 casualties of which 6,359 (65 %) were civilians, Iraq saw the second highest number of civilian casualties from explosive violence in 2016 according to AOAV records. While approx. 4,800 civilian losses were caused by IED attacks, almost 1,000 resulted from air attacks. These figures represent a 26 % increase in the number of civilian casualties compared to 2015. Reports also claim that armed actors suffered 3,426 casualties from the use of explosive weapons (35 %).[30] Though AOAV generally does not claim comprehensive recording (see Syria), such increase would be consistent with the surge of air and ground operations against ISIS and the worsening security situation in Iraq.

Among the worst recorded incidents globally in 2016, an airstrike and an IED attack in Iraq ranked high on the list: A car bomb targeted a commercial market in Baghdad which caused 524 civilian casualties; an airstrike by the US-led coalition hit a busy market in an ISIS-held area in Qaim in which 300 civilians were killed or injured.[31]

Yemen
Due to a temporary ceasefire between April and August 2016, Yemen saw a decrease of 57 % in recorded civilian casualties compared to 2015. However, with 151 incidents and 2,713 civilian victims (accounting for 66 % out of a total of 4,095 casualties) the figure remains still high. According to AOAV records, 82 % of the civilian casualties (approx. 2,249) were caused by air attacks of the Saudi-led coalition. An airstrike against a community hall in Sana’a causing 735 civilian casualties represents the single worst incident in 2016. Destructions have led to a

[27] Deduced from graphic contained in AOAV report, loc. cit., p. 11
[28] Loc. cit., p. 13
[29] Loc. cit., p. 24
[30] Loc. cit., p. 12, 24, 28
[31] Loc. cit., p. 9

humanitarian crisis in Yemen making two thirds of its 18.8 million population depend on aid from outside; yet all sides were denying sustained humanitarian access.[32]

Armed actors in Yemen suffered 1,382 casualties (34 % of all casualties). Armed opposition groups used IED attacks as a tactical means to inflict heavy losses on security forces associated with the government. Such attacks killed or injured 867 combatants accounting for 86 % of all casualties caused by IED attacks in Yemen.[33]

Afghanistan
The security situation in Afghanistan remained tight due to a surge in ground-launched and IED-attacks of Taliban, local militias, Al-Qaeda and ISIS-affiliated groups. 198 recorded incidents resulted in a total of 4,095 casualties of which 2,199 (54 %) were civilians and 1,896 (46 %) armed actors. IED-attacks caused approx. 1,800 civilian casualties. A suicide car bomb in Kabul near the National Security Directorate was among the worst incidents in 2016, killing or injuring 393 civilians. While only one incident was attributed to NATO *Operation Resolute Support*, AOAV did not provide concrete figures regarding Afghan government and (national) U.S. attacks by aircraft, combat drones or special operation forces.[34]

Turkey
The armed violence in Turkey has risen significantly in 2016. According to AOAV records 110 explosive violence incidents caused a total of 2,675 casualties of which 1,825 (68 %) were civilians and 850 (32 %) armed actors. Compared to 2015, civilian losses had almost doubled. According to AOAV 94 % of civilian losses were caused by IED attacks (amounting to approx. 1,710) and 6 % by ground- or air-launched attacks (approx. 110 civilian casualties). IED attacks also killed or injured 757 armed actors and security personnel in 2016.[35]

Within the 110 recorded explosive violence incidents, six car and suicide bombs caused 54 % of the total civilian deaths and injuries (approx. 985). A triple suicide bomb attack in June 2016 at Ataturk Airport, Istanbul, left 40 dead and over 230 injured.

While ISIS is held responsible by Turkish intelligence for most of the IED attacks, the report does not give concrete figures on losses due to the attempted coup d'état of Turkish military units on 15 July 2016 and casualties resulting from the Turkish campaign against the PKK in south-eastern Turkey. In contrast, the report attributes 5 % (~115) of all incidents globally to Turkish security forces (see below).

Pakistan
158 incidents were recorded in Pakistan which resulted in a total of 2,136 casualties due to the use of explosives. 1,498 of them were civilians (70 %), 638 security forces (30 %). Suicide attacks of non-state actors targeted particularly Christians and other religious minorities, representatives of liberal reforms, as well as state security forces that are engaged in campaigns in Pakistan's Federally Administered Tribal Areas (FATA). A suicide bombing targeting Christians at a park in Lahore killed and injured 413 civilians ranking third in the list of the recorded ten worst incidents involving the use of explosives.[36] The report contains no figures on artillery, air or drone strikes carried out by Pakistani security forces or the United States.

[32] Loc. cit., p. 9, 10, 12, 27, 28
[33] Loc. cit., p. 24
[34] Loc. cit., p. 9, 12, 16, 18, 24
[35] Loc. cit., p. 9, 13, 14, 16, 24
[36] Loc. cit., p. 9, 12, 24

Somalia
With 87 incidents and a total of 1,414 casualties, of which 826 (58 %) were civilians and 588 (42 %) armed actors, Somalia saw an increase of 83 % in explosive violence compared to 2015 (451 civilian casualties). The Al-Shabaab militia was responsible for at least 71 % of civilian casualties with IEDs accounting for 74 % of its attacks and causing approx. 600 civilian deaths and injuries. Although operating mainly in the southern and central regions of Somalia Al-Shabaab in 2016 directed over 50 % of its attacks at targets in Somalia's capital Mogadishu which is controlled by AMISOM[37]. Suicide attacks which accounted for 25 % of all incidents in 2016 in Somalia had a disproportional effect causing 52 % of all civilian casualties.[38]

Nigeria
In Nigeria, AOAV recorded 491 civilian casualties from the use of explosive weapons in 2016 which were almost exclusively caused by IED attacks. They represent 56 % of the total of 900 casualties and an 83 % decrease compared to 2015 with 2,920 civilian casualties. This might be the result of a successful campaign against Boko Haram of a Multinational Joint Task Force composed of security forces of Nigeria, Chad, Cameroon, Benin, and Niger around the Great Chad lake region.[39]

Ukraine
AOAV recorded 2,357 civilians killed or injured in the Ukraine conflict between 2014 and 2016, of which 2,096 were attributed to the use of explosive weapons in populated areas. The vast majority of casualties was caused by shelling with indirect fire weapon systems such as artillery and mortars with multiple-rocket launchers causing particularly devastating wide area effects. Hotspots were the areas of Donetsk, Mariupol, Slovyansk, Kramatorsk, Bakhmut, Avdiivka, Krasnohorivka and Kurakhove Maryinka.[40]

The Minsk II-Agreement of 12 February 2015 requires an immediate ceasefire, the establishment of a 30 km buffer zone and the withdrawal of heavy weapon systems from the line of contact (up to 70 km distance, depending on the type of weapon) under the observation of the OSCE Special Monitoring Mission (SMM).[41] It has led to an end of offensive mobile operations and a significant reduction of the intensity of fighting. Despite that, direct fire exchange and indirect shelling flares up from time to time still causing civilian casualties though at reduced levels. E.g., in June and July 2016 fighting in the area of Krasnohorivka and Maryinka intensified and caused 142 civilian casualties including 20 deaths.[42]

1.2.2 Attribution
The fact that in almost all cases the recorded attacks and civilian casualties occurred in context with civil war and internal unrest raises the question of attribution to state and non-state actors. While air

[37] AMISOM = African Union Mission to Somalia
[38] Loc. cit., p. 12, 14, 24
[39] Loc. cit., p. 12, 24
[40] Cf. Harvard Law School International Human Rights Clinic and PAX: Operating under Fire, May 2017, p. 2, 22
[41] Paragraph 2 of the Minsk Agreement of 12 February 2015 requires the withdrawal of all heavy weapons by both sides by equal distances in order to create a security zone of at least 50 km wide from each other for the artillery systems of calibre of 100 and more, a security zone of 70 km wide for MLRS and 140 km wide for MLRS Tornado-S, Uragan, Smerch and Tactical Missile Systems (Tochka, Tochka U). Full text of Minsk agreement of February 12, 2015, in: Financial Times, 12 February 2015. https://www.ft.com/content/21b8f98e-b2a5-11e4-b234-00144feab7de accessed 2 October, 2017
[42] Harvard/PAX: Operating under Fire. Loc. cit., p. 22

attacks were almost exclusively carried out by state actors, ground attacks were predominantly and IED attacks exclusively launched by non-state actors.[43]

According to AOAV, incidents that could unambiguously attributed to state or non-state actors or both with a remaining number of unknowns (11% of incidents) suggest the following distribution of responsibility for civilian casualties in 2016 (*estimated numbers deduced from percentages in italics*):[44]

Attribution to	Non-state actors	State actors	Both	Unknown	Total
Number of actors	60	26			
Incidents	approx. 41 %	approx. 48 %		*253* (11 %)	2,300
Total casualties	24,726	18,838	2,060		45,624
Casualties of Armed actors (%)	5,727 (23 %)	7,525 (40 %)	(*47*)	(237)	13,536
Civilian casualties (%)	18,999 (77 %)	11,313 (60 %)	(*296*)	(*1,480*)	32,088
Percentage of overall Civilian casualties	55 %	35 %	1 %	5 %	

Compared to 2015, the number of civilians killed or injured by 26 *state actors* in 2016 increased by 9 %. They were collectively responsible for approx. 11,300 civilian casualties. Main state users of explosive weapons were the US-led coalition against ISIS in Iraq and Syria (17 % of incidents), national U.S. strikes (5 %), Turkey (5 %), Syria (10 %) and the Saudi-led coalition in Yemen (10 %).

Of the 170 incidents where the *state* perpetrator was unknown, 124 took place in Syria of which 119 were air-launched attacks. As only states use aircraft or combat drones, the attribution to state actors will be higher than indicated in the above figures for state actors. In Syria, there was an increase of air attacks in 2016 in the provinces of Aleppo (particularly against the besieged city of East-Aleppo), Idlib, Damascus, Homs, Hama, Raqqa and Deir ez-Zour carried out by the Syrian and Russian air forces. Therefore, AOAV believes that most of the 119 air attacks (accounting for almost half of all unknown incidents) should be attributed to either the Syrian or the Russian air force.

No figures were provided on the effects of the U.S.-led coalition campaign in Syria that struck targets in areas held by ISIS (Ar-Raqqa, Deir ez-Zour, al-Hasakah) and Al-Qaeda affiliates in the provinces of Aleppo and Idlib. The report did also not mention a number of sorties flown by the Turkish air force against Kurdish armed actors in the Northern Aleppo province, and Israeli airstrikes that targeted Hezbollah units in Southern Syria.

A recorded number of 60 *non-state actors* were collectively responsible for approx. 19,000 civilian casualties. Main non-state users of explosive weapons were ISIS in Iraq and Syria (19 % of all

[43] J. Dathan, AOAV: Explosive Truths. Monitoring explosive violence in 2016. Loc. cit., p. 24, 29, 30
[44] Loc. cit., p. 14, 16

incidents), Syrian rebels (11 %), PKK (4 %), Houthi-rebels in Yemen (3 %) and the Al-Shabaab militias in Somalia (3 %).

ISIS took responsibility for approx. 50 % of the 350 assigned IED attacks.[45] For 515 incidents perpetrated by non-state actors, no specific non-state group claimed responsibility. Of these incidents, 19 % took place in Iraq, 14 % in Pakistan, 10 % in Afghanistan, a number of incidents also went unclaimed in Egypt, Thailand, India, Turkey and Somalia.[46] In consequence, the number of casualties caused by non-state actors might actually exceed the above figure.

87 % of all recorded incidents resulting in civilian casualties were caused by the following main state and non-state users of explosive weapons in 2016:[47]

States (coalitions)	*Incidents*	*Non-state actors*	*Incidents*
U.S.-led coalition	17 % (~390)	ISIS (*mainly in Iraq and Syria*)	19 % (~420)
USA (national)	5 % (~115)		
Syria	10 % (~230)	Syrian rebels	11 % (~250)
Turkey	5 % (~115)	PKK	4 % (~ 90)
Saudi-led coalition	10 % (~230)	Houthi rebels	3 % (~ 70)
		Al Shabaab	3 % (~ 70)
Total	47 %		40 %

1.3 Assessment

1.3.1 Methodology of data collection and evaluation

AOAV has collected its data base from “reliable media reports”, i.e. English speaking press sources, predominantly the renowned Associated Press (AP), Agence France Press (AFP) and Reuters.[48] However, as news agencies are not always in a position to get unlimited access to the concerned areas and actors, pending the level of political and military control, and to analyse fully Arab and other foreign language sources, their coverage of the situation might not always be complete and comprehensive. Since these agencies are generally well connected (“imbedded”) with western actors, that have developed media strategies, they might reflect their reports more comprehensively than those of other actors. Also civil society actors that are engaged in humanitarian assistance often work with one side of the conflicts and view the recollection of events by their opponents, particularly state controlled media, with scepticism.

The first victim of war, however, is the truth as all sides involved are engaged in propaganda and try to represent their cause and action in a positive light. They either want to portray own military action – particularly air attacks – as efficient, i.e. striking mainly combatants, or denounce the opponent for flagrant violation of the basic rules of humanity in order to attract international support. In most of the areas concerned an impartial third party observation (such as the OSCE Special Monitoring Mission in Ukraine) is not in place which could bring about a less biased picture of the situation. In areas under ISIS control very limited reliable information on the real situation on the ground is available.

[45] Loc. cit., p. 24
[46] Loc. cit., p. 16
[47] Ibid.
[48] Loc. cit., p. 36

Against this backdrop, AOAV admits that not all incidents and casualties could be reliably recorded and, therefore, does not claim to represent a full coverage of incidents and casualties.[49] Thus, the number of casualties among civilians and armed actors, particularly in Syria and Iraq, could be significantly higher than recorded. E.g., in Syria there remains a significant discrepancy between recorded numbers of casualties due to the use of explosive weapons and the overall number of casualties since 2011 as claimed by UN sources which needs further explanation.[50]

What is also striking in this context is the unusual high percentage of fatalities (36 %) among recorded casualties. It either points to serious deficiencies as to the quality of rescue chains and emergency operations in hospitals which have suffered from degradation due to bombings, or to gaps in reporting injuries. The overall decrease of numbers of casualties by 2 % in 2016 as compared to 2015 stands in stark contrast to the 7 % increase in numbers of reported fatalities. AOAV assumes that the decrease might be caused by reports focusing on fatalities only while ignoring or not properly reporting injuries.[51]

Also the recorded total number of 2,600 casualties among armed actors in populated areas (including 1,800 caused by IED attacks) is surprisingly low and might need a significant correction. It stands in stark contrast to the recorded total of 10,900 casualties among armed actors in non-populated areas although towns and cities were the centres of combat while open field battles were largely avoided. It seems quite unlikely that the fierce fight throughout several months in Aleppo, Mosul, Raqqa and other populated centres, which involved several attacks and counter attacks before it finally ended with the defeat of non-state actors, would result in less than 300 fighters killed *and* injured on *both* sides by ground-launched explosive weapons and approx. 500 casualties due to air attacks with a combined maximum of 290 fatalities.

These considerations put into question the methodology of AOAV to assume that "*all casualties are recorded to be civilians unless otherwise stated*."[52] Though AOAV does not totally exclude that among those recorded as civilians could be also armed actors, it claims that this could be the case only in a maximum of 3 % of all recorded incidents[53] (amounting to an estimated maximum of additional 900 casualties among armed actors). However, this assessment does not only neglect the media strategies of opponents but also the character of non-international asymmetric warfare: Irregular armed formations, terrorist groups and armed civilians cannot always be clearly distinguished from civilians by their appearance but might still pose lawful targets. In many cases irregular fighters disguise in civilian clothes to prepare surprise attacks or withdraw unrecognized from the area of combat. In these instances, they should not be counted under "civilian casualties".

Such doubts are fortified by a further consideration: The reported number of 500 women killed or injured in 200 incidents seems quite low compared to the overall number of more than 32,000 civilian casualties in 2,300 incidents. If one assumes that such recorded female casualties were representative for all incidents the resulting figure would amount to about 5,500 female casualties. Assuming that also the number of killed or injured children (about 1,500 in 340 incidents) was representative for the majority of cases one could conclude that about 10,500 male and female children were among the casualties caused by the use of explosive weapons. However, even with such highly speculative calculations the high number of remaining casualties among male adults – about 16,000 – would be significantly out of proportion.

[49] Ibid.

[50] The United Nations assume that the war in Syria has caused more than 400,000 fatalities. Cf. UN General Assembly A/RES/71/203 of 1 February 2017, Resolution adopted by the General Assembly on 19 December 2016 titled "*Situation of human rights in the Syrian Arab Republic*"

[51] J. Dathan, AOAV: Explosive Truths. Monitoring explosive violence in 2016. Loc. cit., p. 9

[52] Loc. cit., p. 36

[53] Loc. cit., footnote 60 on p. 42

In conclusion, the sum of killed and injured armed fighters in populated areas seems to be significantly higher than AOAV suggests – and the number of civilian casualties would have to be corrected accordingly. In any case, it seems worth re-examining the plausibility of the recorded data.

However, despite such reservations, there is no doubt that the AOAV report has collected valuable data by differentiating casualties caused by various types of attacks and various weapon systems in use and by pointing at a trend that gives reason to concern: It seems obvious that the number of civilian casualties caused by the use of explosive weapons in populated areas is unacceptably high and poses a serious challenge to the international community. Even corrected figures demonstrate the disproportionate effects of explosive weapons in populated areas and point to both a particular risk of civilians and a trend to indiscriminate warfare in contemporary wars or even deliberate attacks against civilians by terrorist acts in urban centres.

1.3.2 Patterns of conflict, types of attacks and attribution

While a number of terrorist attacks were launched also in countries not affected by war, the vast majority of recorded cases in which civilians became victims of the use of explosive munitions occurred in context with internal unrest, civil war and non-international armed conflict. That raises the question of attribution to state and non-state actors. While air attacks were almost exclusively carried out by state actors, ground attacks were predominantly and IED attacks exclusively launched by non-state actors.[54]

It is striking that 45 % of all civilian casualties resulting from the use of explosive weapons in 2016 were caused by IED attacks (about 14,300) which were exclusively carried out by non-state actors. Some 900 IED attacks were recorded in 48 states and territories, among them 20 countries that were not mentioned in 2015, as opposed to 42 countries affected by ground-launched attacks and 15 states and territories that have suffered under air-launched attacks. I.e., many countries that have not seen wars or warlike armed violence during internal unrest became targets of terrorist attacks carried out by loosely connected armed groups or individuals which were inspired by common ideologies rather than organized structures.

Such attacks have the intention to kill and injure as many people as possible, mainly “unbelievers” and “heretics”, under the pretext of allegedly religious or jihadist motivation. To achieve such inhumane objectives, jihadist perpetrators seek highly populated areas and target mainly public places such as commercial centres, markets or places of worship with a high density of assembled people.

However, the deliberate killing of civilians by terrorists does not fall in the category of indiscriminate or disproportional warfare in populated areas and require different approaches by states. Putting such terrorist action in the same basket with military operations in context with non-international or international armed conflict means blowing up overall figures and blurring the differences rather than clarifying the effects of indiscriminate or disproportional warfare through air- or ground-launched attacks.[55]

In a number of cases, however, IED attacks by armed non-state actors have targeted military formations and other armed actors during armed conflict. Notably in Yemen, Syria, Iraq and Afghanistan IED attacks have become a pattern of asymmetric warfare of rebel factions causing

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[54] Loc. cit., p. 24, 29, 30

[55] Cf. United Nations General Assembly Resolution adopted on 5 December 2016 titled: “*Countering the threat posed by improvised explosive devices*” (A/RES/71/72 of 15 December 2016)

painful losses also among professional military or other state and non-state armed formations. Although such action does not deliberately target civilians it still demonstrates the readiness to wage indiscriminate and disproportional warfare in internal conflict.

The majority of ground-launched attacks are carried out by non-state actors though they are not always tied to rebel factions and in several cases support governments, e.g. Shia militias in Iraq and Syria. A number of non-state actors which are not associated with governments even fight each other, e.g. rebel factions competing for power such as the Salafist Ahrar as-Sham, the jihadist al-Qaeda affiliate Jabhat al-Nusra, the Islamist Jaysh al-Islam or the Kurdish dominated Syrian Democratic Forces fighting ISIS and Turkish-led Syrian rebel groups simultaneously.

It is striking that the use by state and non-state actors of ground-launched indirect fire weapon systems with their inherent large area effects, significant imprecision and high inaccuracy have caused less civilian casualties (22 %) than air-launched weapons (31 %) though the number of recorded air- and ground-launched incidents was almost equal (660-670). One reason could be incomplete or inaccurate reporting. However, the differences in qualities of intelligence, targeting equipment, precision of munitions, operational routine and rules of engagement between western, Russian, Syrian and other Arab air forces might have played a significant role.

The war in Syria has been characterized by the destruction of residential areas. In particular, massive air attacks against the besieged East-Aleppo have informed accusations against Syrian and Russian air forces of waging indiscriminate warfare. In Syria, 48 % of all casualties due to the use of explosives were caused by air attacks, i.e. 6,385 civilians killed or injured. Although the figure includes air attacks by the U.S.-led coalition in the Deir Ezzor, al-Hasakah, ar-Raqqa, Northern Aleppo (here also Turkish air force) and Idlib provinces (areas that account for max. 20 % of overall casualties), the vast majority of casualties by air attacks in Syria was obviously inflicted by the air forces of Syria and Russia. It seems noteworthy, however, that ground-launched and IED attacks together caused as many civilian casualties in Syria as air attacks (both well beyond 6,000).

The war in Iraq was characterized by the combined offensive operations of the U.S.-led coalition against ISIS with a focus on the re-conquest of the city of Mosul while parallel attempts were made by various forces and armed groups in Syria to reconquer the city of ar-Raqqa. Generally, populated areas such as larger settlements, towns and urban terrain were used by ISIS and other armed groups as military strongholds, centres of communication and logistics, industrial production and commerce, administration, propaganda and recruiting. From there, expedient strikes with quick and surprising land movements were launched to target and conquer adjacent areas.

While the ground war in Iraq was carried out mainly by Kurdish Peshmerga, Iraqi government forces and Shi’ite militias, the air war was conducted by the U.S. and allied air forces. In 2016, the war resulted in a total of almost 10,000 recorded casualties of which more than 6,300 (65 %) were civilians. Approx. 4,800 were caused by IED-attacks. However, despite modern equipment and tight rules of engagement, also western air forces have inflicted severe civilian losses in Iraq (almost 1,000) reaching up to 300 casualties in one incident. The Saudi-led coalition, which uses modern western aircraft and munitions as well, has caused high civilian casualties in Yemen amounting to 1,840 in 2016 (82 % of overall casualties) with up to 735 casualties in one single incident. Such outcome raises the question why also modern munitions and targeting techniques can result in such high numbers of casualties.

The general patterns of these conflicts – particularly in Syria, Iraq, Yemen and Afghanistan – suggest that the ground war is carried out predominantly by regional regular and irregular formations – often resorting to hit and run-tactics such as IED attacks – while intervening states use superior air forces to turn the balance and reverse rebel momentum. The asymmetry between regional and intervening forces in operational capabilities and quality of organization, intelligence, command and control, armaments, training and cohesion is striking. Government forces and irregular armed groups in such war-torn countries suffer from exhaustion and deteriorating military potentials. That explains to some extent their low military performance also in regard of use and targeting of explosive munitions.[56]

In these countries, government and irregular forces alike can keep low-level operational capabilities only by the steady flow of logistical supply and arms deliveries provided by intervening powers. However, such asymmetric scenarios would not be typical for international armed conflicts between states with advanced military capabilities and, therefore, do not allow for far-reaching conclusions as to military operations under different conditions.

Lastly, the fact that almost 60 % of all civilian casualties were caused by non-state actors raises the question how tighter restrictions for operations of state armed forces in populated areas could curtail those of non-state actors and how states should tackle this problem.

1.4. Preliminary conclusions

(1) High civilian casualties resulting from the use of explosive munitions in populated areas give reason for concern. While the numbers recorded by AOAV are incomplete they point at a trend towards disproportional or indiscriminate warfare in contemporary wars.

(2) In some instances, the plausibility of recorded numbers needs to be re-examined. Against the backdrop of asymmetric war, the method of counting every casualty as civilian who is not expressively described by public sources as combatant seems questionable.

(3) Recorded numbers distinguish between air-launched, ground-launched and IED-attacks. Summarizing recorded numbers between 2011 and 2016, IED attacks account for more than half of all civilian deaths and injuries while ground-launched attacks have caused 22 % and air-launched attacks 18 % of civilian casualties though the latter rose to 31 % in 2016. IED attacks were carried out exclusively and ground-launched attacks mainly by non-state actors; air attacks were launched exclusively by state actors.

(4) Most of the IED-attacks were terrorist actions deliberately targeting civilians not only in countries affected by internal unrest or non-international armed conflict but also in states that live in peace. However, such deliberate killing of civilians by terrorists does not fall in the category of indiscriminate or disproportional warfare and requires different approaches by states. Putting terrorist action in the same basket with military operations inflates overall figures and blurs the differences rather than clarifying the effects of indiscriminate or disproportional warfare through air- and ground-launched attacks.

(5) The vast majority of recorded cases in which civilians became victims of the use of explosive munitions occurred in context with internal unrest, civil war and non-international armed conflict. Under such conditions ground attacks are carried out mainly by increasingly

[56] The low military performance shown by Syrian-Arab irregular forces under Turkish command during *Operation Euphrates Shield* (August 2016 – March 2017) serves as an example. Cf. Metin Gurcan: *Turkish Intervention: Ankara's lessons from Euphrates Shield*. In: Jane's, date posted: 09-June-2017, p. 5-8

disorganized government forces and irregular armed formations that lack the military capabilities necessary for precise use of munitions and accurate targeting. They have little ability to carry out organized mobile operations and often resort to asymmetric hit and run-tactics or indiscriminate area fire to cause attrition of enemy forces.

(6) In contrast, intervening states use superior air forces to turn the balance and reverse rebel momentum. However, the increasing civilian casualties resulting from obviously disproportionate air attacks in 2016 give reason to concern. Also the use of advanced precise munitions and accurate targeting methods often results in civilian casualties.

(7) Against this background, area effects of and targeting methods for various types of ground and air munitions must be analysed to understand means and methods of warfare and find ways to diminish civilian casualties resulting from the use of explosive munitions.

(8) However, the fact, that almost 60 % of all recorded civilian casualties were caused by non-state actors raises the question how tighter restrictions for operations of state armed forces in populated areas could curtail those of non-state actors and how states should tackle this problem.

(9) With a view to potential international action, the patterns of asymmetric warfare with its tendency towards disproportional and indiscriminate use of explosive munitions should be taken into consideration and politics revised that grant military support to armed actors involved in internal wars.

(10) However, such asymmetric scenarios would not be typical for international armed conflicts between states with advanced military capabilities. Therefore, they do not allow for far-reaching conclusions as to military operations under different conditions.

Part II

Armaments: Use and Effects of Explosive Weapons in Contemporary Wars

2.1 Principal weapon categories in use capable of delivering explosive warheads

The statistical survey in Part I of this paper shows that in contemporary wars civilian casualties resulting from the use of explosive weapons are caused by attacks with Improvised Explosive Devices (IEDs) as well as air-delivered and ground-launched munitions. While IED attacks were observed that aim at military targets (e.g. in Afghanistan, Yemen and Syria), in most cases such attacks are of a terrorist nature deliberately targeting civilians. Their purpose is to undermine a country’s political and social stability, incite hatred between different ethnic and religious groups or carry out a global Jihad in countries not directly affected by internal or regional wars. Terrorist attacks want to kill as many people as possible and consequently seek to achieve their goals by selecting densely populated areas for IED-detonations, in particular crowded places like markets, commercial centres, traffic choke points and places of worship.

Perpetrators of deliberate attacks on civilians are inaccessible to humanitarian considerations. Therefore, such attacks cannot be tackled by the attempts of states to enhance compliance with International Humanitarian Law and prevent indiscriminate and disproportionate warfare in order to better protect civilians from the effects of explosive weapons in populated areas. Against this backdrop, the following chapter is confined to ground and air delivery systems and munitions, their technical characteristics, targeting requirements and use in current conflicts.

For *air-delivered attacks* aircraft, helicopters and armed drones (*Unmanned Combat Aerial Vehicles*, “UCAV”) are used that are capable of dropping unguided or guided bombs or launching unguided rockets or precision-guided air-to-surface missiles. While all such munitions have area effects they differ in yield, composition of warheads and precision of delivery. Which munitions are used depends on the targets aimed at, the surrounding conditions, and, in particular, the technological standards of air forces deployed in the region of conflict in context with available stocks. E.g., special armour-piercing or deep earth-penetrating munitions might be used in combination with precise terminal-phase guidance. As such advanced munitions are costly and stocks limited also elder types of munitions are used, however, within a more or less reliable targeting system.

Principally, the U.S.-led and Saudi-led coalition air forces as well as the Russian air force are capable of using precise weaponry and modern targeting technology. In contrast, after years of deteriorating combat power the Syrian air force uses what is left of its elder Soviet equipment and – despite Russian logistical support – even resorts to producing and dropping improvised air bombs (“*barrel bombs*”) that lack any aerodynamic qualities and methods of delivery suited for accurate targeting.

For *ground-launched attacks* involving explosive munitions with wide area effects, mainly indirect fire weapon systems (IFWS) are used such as self-propelled or towed artillery pieces, mortars and multiple-barrel rocket launchers (MBRL). They can engage targets at distances beyond visual range, natural elevations or built structures. While IFWS fire explosive shells and rockets from barrels at high ballistic trajectories, direct fire weapon systems (DFWS) such as tank and anti-tank guns or anti-aircraft and machine canons aim directly at targets within visual range and fire explosive projectiles or kinetic energy rounds at much flatter trajectories.

As opposed to the air war which is conducted by modern air forces, ground-launched attacks in the areas of contemporary wars are predominantly carried out by non-state actors – either in opposition to or in support of governments as can be observed in Syria, Iraq, Yemen, Libya and Somalia. After years of conflict, also remaining government forces resemble more and more hastily raised militias with rudimentary organization, weaponry and training rather than professional, well organized, equipped and trained armies. At the same time, almost all sides in such conflicts are supported by intervening regional and global powers. Without their arms and ammunition supplies, logistic support, intelligence, command, control and communications, training as well as direct combat action and air support the war between warrying factions in Syria could not have been sustained throughout a period of six years’ continued fighting. Such support included a steady flow of ammunition and delivery to rebel units of modern anti-tank guided weapons such as the U.S.-made anti-tank guided missile system (ATGM) TOW which can also be used to down low flying helicopters.[57] Furthermore, Iran, Arab and western States organize, equip, train and lead militias, particularly in Iraq and Syria.

[57] In July, 2017, the U.S. has stopped the covert CIA-led program of weapons deliveries to rebel groups in Syria, labelled “moderate”, which was initiated in 2013 in cooperation with Turkey, Jordan and Saudi-

In consequence of that development, the ground armaments used by government forces, affiliated militias and major armed factions in Syria do not differ in principle, though government forces might still retain some numerical advantages: All sides use elder Soviet-made tanks, armoured combat vehicles and artillery of the same types.[58] Self-made mortars and MBRL ("*hell canons*") complement the arsenals of armed rebels which are even less capable of precise targeting than the elder Soviet equipment. Eventually, in 2016 the Russian air campaign made the difference.

2.2 Area effects of explosive weapons

Technically, area effects of explosive weapons are caused by weapons and munition characteristics as well as targeting conditions. However, for military reasons, such effects can be intended to cope with mass targets or engage single targets where precise location is not possible. Only most advanced guided munitions are capable of hitting precisely the intended aim point provided target situation assessments are correct and the time gap between target selection and munition delivery is small enough to avoid changes in the target area which could also lead to targeting errors. Thus, there are four principal reasons that cause wide area effects of explosive munitions even if attacks are intended to be confined to military targets:

(1) All detonations of explosive weapons have area effects even if hitting precisely the aim point.

(2) Inherent inaccuracies of targeting processes, firing procedures and communication, imprecision of delivery systems, various types and production lots of munitions, charges and fusions, as well as environmental conditions influence trajectories of projectiles or rockets and times of detonation. They cause – often significant – deviations of the point of impact from the aim point and result in enlarged lethal and incapacitating areas.

(3) Unclear and rapidly changing battlefield conditions with enemy counter-measures, quick target movements and fluid combat situations cause insufficient intelligence and target reconnaissance, disruption of communications and delays of weapon delivery in the targeted area which can lead to false situation assessments and failures of targeting.

(4) In many cases, area effects are intended to achieve the military purpose and, to that end, multiplied by repetitive firing of groups and salvos of shells and rockets.

2.2.1 Effects of detonations of explosive projectiles and (rocket) warheads

Destruction and incapacitation effects of explosive munitions result from a substantial blast and metal fragmentation radius around the point of detonations. While the shock wave can destroy hard targets such as armoured vehicles and concrete walls, fragments flying with high speed from the point of burst can kill "soft" targets and penetrate light armour. The radius of such effects depends on the yield and point of detonation (surface, sub-surface or air burst) in combination with the characteristics of the environment in which the detonation occurs.

Arabia. The program was run through operations rooms in Turkey and Jordan and mainly helped rebels operating along the Turkish and Jordanian borders. A different program run by the Pentagon continues to support Kurdish-Arab militias of the "Syrian Democratic Forces". Cf. David E. Sanger, Eric Schmitt, Ben Hubbard: "*Trump Ends Covert Aid to Syrian Rebels Trying to Oust Assad*". The New York Times, 20 July 2017

[58] International Institute for Strategic Studies: *The Military Balance 2017*. London 2017, Chapter VII, p. 404-407

There is always a lethal radius around the point of impact in which the blast combined with fragments destroys hard materials and kills human beings. However, fragments are dispersing in a wider radius that can still incapacitate and kill unprotected human beings and damage materials although the overpressure of the blast and the speed and density of fragments diminish with increasing distance from the point of impact. Thus, the probability of direct effects of explosive munitions on unprotected human beings and hard materials is diminishing with growing distance to the point of impact. Generally, the radius of lethal and damaging blast is significantly lower than that of dispersing fragments. It is self-evident that “soft targets” are endangered in a wider radius than protected “hard targets” such as battle tanks, armoured vehicles, basements and buildings made of stable stone walls or hardened shelters made of reinforced concrete.

In principal, blast and fragments spread spherically around the point of impact if not interrupted by natural elevations and obstacles or hard materials. However, the point of detonation can be set by fuses that either ignite on impact on the surface or shortly before in the air or with a time delay after impact. For such capabilities, variable-time or proximity fuses with range-measuring sensors are in use that are integrated in the projectiles or rocket warheads.
In the case of a surface burst the blast creates a crater in the ground and extends mainly in a hemispheric way and 360° circle around the point of impact while the fragments disperse flatly above ground. In consequence, human beings protected by walls, ditches or basements have a higher chance of survival than unprotected ones if not hit directly. However, if such detonations occur in narrow streets and markets or inside hardened structures and buildings, surrounding walls either channel or contain and reflect the overpressure while fragments hit walls and generate ricochets and chipping off. In such cases, the effects of explosions are multiplied.[59]

In the case of an air burst the blast will be partially absorbed in the atmosphere (pending the distance to the ground). However, fragments flying with high speed through the air will cover a wider circle on the ground if not hampered by obstacles although their density will diminish with growing distance from the point of the air detonation. Thus, a significant portion of fragments will hit the surface within a wider radius and, below the point of detonation, with a steep angle reaching deep into ditches and defilades or behind elevations and walls. While this mode of employment is intended to incapacitate combatants dug in field positions and entrenchments, fragments resulting from air bursts can also hit civilians assembled in narrow streets wrongly believing that surrounding houses will provide protection.

If time delays of detonations are combined with penetration capabilities of hardened warheads, hard targets such as shelters and bunkers can be penetrated with the explosion power multiplying inside such structures. Buildings erected on top might collapse. Explosions deep below runways and streets would not only produce craters but also turn up and destroy the paved surface in a wider circle.

Summarizing, urban terrain with solid structures, buildings and basements can provide a certain degree of protection against the effects of explosive weapons at some distance from the point of detonation. However, direct hits and impacts in narrow streets and places or inside buildings can multiply such effects with devastating consequences. Beyond direct hits also the secondary effects of repeated explosions in the vicinity of buildings can cause serious damage: high-speed impacts of fragments and overpressure shock waves shatter window glass, generate debris, ricochets and

[59] The following sources contain very useful descriptions of wide area effects of explosive munitions, particularly in urban terrain: Samuel Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Final Report. GICHD, Geneva, February 2017, p. 42-61, 88-97. PAX / Article 36: Areas of harm. Understanding explosive weapons with wide area effects. Colophon, October 2016, p. 8-22

spalling also inside buildings and shake the stability of structures which can eventually lead to their collapse and result in more casualties.

It is important to note that such effects of explosions principally occur no matter how precisely the projectile, shell or rocket hits the aim point. Therefore, it is not the precision of impact points relative to the aim point which curtails the physical effects of explosions as such but rather the yields and compositions of warheads and other tailoring measures which can reduce the lethal and incapacitating radius around the point of detonation. However, in battle such immediate weapons effects are multiplied by inaccuracy of targeting and inherent technical imprecisions of delivery and resulting trajectories which can lead to significant deviations of the impact points from the aim points.

2.2.2 Imprecision of delivery and inaccuracies of targeting processes

The precision and accuracy of the point of detonation of a warhead relative to the aim point depend on various factors relating to technical features of selected delivery systems and munitions, environmental conditions as well as targeting processes.

Weather conditions, various types of payloads and small differences in manufacture of bombs, projectiles and rockets influence their aerodynamic qualities while also different ranges, technical conditions of barrels, differences in charges and fuses and the position of firing platforms on the ground or in the air lead to differences in trajectories and cause deviations of the actual point of impact from the intended aim point. I.e., no bomb, projectile, shell or rocket of the same type delivered from the same platform under seemingly equal conditions and aiming at the same target point will hit precisely the same impact point.

As the impacts of a series of such deliveries oscillate around the aiming point, the usual measurement for such imprecision is the Circular Error Probable (CEP). It defines the distance in a radius from the aim point in which 50 % of all deliveries would impact. In consequence, 50 % of the deliveries would impact outside the CEP. For a delivery to impact in a defined area with a 93 % probability usually the value of two CEPs is applied while 99.8 % of deliveries are assumed to impact in a circle covering 3 CEPs. In battlefield realities such areas of deviations often take the form of an ellipse with the longer side extending in the direction of the trajectories (range deviation) while the traverse deviation can be significantly smaller.

The exact values of such CEPs depend on the types, models and technological and quality standards of various delivery means and munitions, the distances between firing position and aim points, and the conditions under which such munitions are delivered. However, CEPs do not take into account inaccuracies resulting from target acquisition and targeting processes. As most IFWS munitions are delivered from firing positions beyond visual range, observed delivery depends on the professional skills and uninterrupted communications of forward observer teams who locate and track the target and guide the targeting process. Technical observation relies on target acquisition sensors while unobserved delivery proceeds on the basis of general situation assessment and – often pre-planned – map-firing.

Therefore, professional training of the crews observing targets either visually or using sensors, evaluating intelligence, surveillance and reconnaissance (ISR) results, calculating trajectories and controlling delivery, operating delivery systems and munitions is crucial to ensure accuracy of targeting procedures and handling of delivery systems, munitions, charges and fuses. Under battlefield conditions, their performance might be degraded by counter-measures of the adversary such as mobile operations and frequent changes of positions, electronic disruption of communications, counter-fire, camouflage and deception.

Highly advanced munitions and sub-munitions with precise terminal-phase guidance assure very low CEPs. They are principally capable of precisely hitting a selected aim point and, thus, matching the impact point with the position of a located military target. However, such qualities are not sufficient to assure concentrating detonation effects exclusively on military targets: *First*, the intelligence-based target selection must be reliable; *second*, the reaction time between target acquisition and weapons delivery must be short enough to prevent changes in the target area; and *third*, the delivery conditions must allow uninterrupted precise guidance (e.g. laser illumination).

2.2.3 Role of reliable ISR and reactivity of munitions delivery for accurate targeting

Accurate intelligence and target selection is a *conditio sine qua non* to meet both military objectives and restrictions by international humanitarian law. Even highly precise delivery could fail to achieve the military purpose and produce devastating effects on civilians if based on false assessment of the nature of the target, its location and the situation of the civil population in the impact area. Unclear situations and the collocation of military targets and civilians complicate the process and might lead to disproportional effects even if not intended. In some scenarios, a party to the conflict might deliberately chose firing positions in the immediate proximity of civilians either to use them as protective shields or to provoke civilian casualties that could be blamed on the opponent.

Moreover, sustainability of target surveillance and reactivity of weapons delivery are crucial to avoid time delays that could lead to changes in the target area. The more time elapses between target reconnaissance and delivery of munitions the less targets are likely to remain in the detected positions while undetected civilians could move towards the target area. Therefore, uninterrupted target identification, tracking and sustained guidance of delivery are crucial to achieve the intended military impact and avoid targeting errors. To that end, reliable intelligence, ground surveillance and reconnaissance (ISR) as well as flexibly deployable weapon systems capable of quick reaction-attacks are needed.

Surveillance of the battlefield, target reconnaissance, acquisition and tracking, as well as delivery-guiding observation can be provided by combat reconnaissance patrols (visual range), far-range (in-depth) reconnaissance by special operation forces, forward artillery observers and air control teams, air reconnaissance and surveillance by aircraft, unmanned aerial vehicles (UAV) and helicopters as well as ground- and air-based sensors such as ground surveillance and artillery radars, sound and flash ranging, signal intelligence, etc. Under such conditions, ground-attack fighter bombers (FBA), armed combat drones (UCAVs) and long-range artillery with terminal-phase guided target-seeking munitions are in a position to react quickly, accurately and precisely.

However, in most contemporary wars, only intervening powers dispose at advanced ISR, delivery systems and munitions while indigenous regular and irregular units lack modern armaments, targeting equipment and professional skills. Ill-equipped and poorly trained and organized units are more likely to produce targeting errors and delivery failures even if the intention was to avoid indiscriminate warfare. But also well-equipped forces often fail to assess the situation in the target area correctly. In such cases, also the use of advanced precise munitions can have devastating effects killing and injuring hundreds of civilians (see p. 9-12, 15-16).[60]

[60] The negative impact of poor intelligence though precision-guided munitions (PGM) were used became obvious when two GBU-38 bombs were delivered by a U.S. F-16 FBA on request of a German commander in Amerkheil, Kunduz, Afghanistan on 4 September 2009, killing several militants and up to 142

2.2.4 Intended area effects
There are three major military reasons why area effects of explosive weapons can be intended in order to achieve military objectives and fulfil an operational mission:
(1) suppress and annihilate mass targets that are deployed in a wide area and have to be engaged simultaneously;
(2) defend key terrain such as vital defence positions and lines of communications including river lines or gaps between natural obstacles or urban terrain, and deny enemy approaches towards those areas;
(3) destroy or incapacitate single targets that are deployed in a wider target area but cannot be accurately located or precisely targeted such as camouflaged artillery observation posts, direct fire systems in fortified positions, frequently changing artillery firing positions, advancing combat units, logistic columns in motion or other mobile targets.

To fulfil such tasks artillery batteries or groups deliver observed and unobserved fire against close and far distant targets including map-firing within pre-planned fire zones or barrages in front of own troops' forward positions to stop assaulting enemy forces. Area effects are enhanced through sustained repetitive firing of groups and salvos of shells and rockets.

Air attacks delivering guided and unguided bombs, or air-to-ground rockets and guided missiles carry out similar missions. They include close air support for forward deployed combat troops guided by forward air controllers, battlefield interdiction operations against advancing enemy units, assembly areas, artillery firing positions or logistical transport along main lines of communications, as well as interdiction operations in the depth of enemy marshalling and deployment areas. Counter-air operations are to destroy enemy air power and incapacitate its air defences (SEAD).

Such air and ground area attacks are typical for largely symmetric, high intensity battles, e.g. in national defence and full-scale internal war scenarios. In contrast, stabilizing operations in asymmetric low-intensity conflicts require precise single strikes against pin-point targets under tight restrictions.

2.3 Ground-launched indirect fire weapon systems (IFWS)

2.3.1 Delivery systems, munitions, effects
Indirect fire weapon systems (IFWS) deliver explosive projectiles (shells) and rockets from tubes over distances between approx. 1 and 70 km – depending on the system used – with a significantly higher ballistic trajectory than directly aiming (line of sight) weapons. With such characteristics they can engage fixed and mobile, hardened and soft enemy targets at far distance beyond visual range, including those behind protections, obstacles, hills or walls that cannot be engaged by directly aiming weapons.

IFWS are composed of three sub-categories:
- Mortars fire explosive rounds at short ranges (1-7 km) with very steep ballistic trajectories;
- Towed field artillery pieces and self-propelled artillery fire shells at medium ranges with medium to high ballistic trajectories (howitzers) or long ranges with flatter trajectories (canons). Some systems combine both characteristics.
- Multiple-barrel rocket launchers (MBRL) deliver mainly unguided rockets at various ranges depending on the system.

civilians. Cf. S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 99

Explosive projectiles (shells) are propelled through the gun barrel by separate charges while rocket propellants are integral parts of the rocket themselves. All projectiles, shells or rocket warheads consist of different mixtures of high explosives and metal fragments or sub-munitions such as mines and end-phase guided armour-piercing projectiles. They explode either on impact or shortly before or after impact – depending on the type of munitions and the setting of fuses.

Rifled barrels cause projectiles to rotate along their length axes in order to stabilize trajectories. Alternatively, fin-stabilized non-rotating projectiles are used. Rocket assisted projectiles (RAP) can increase ranges of field and self-propelled artillery. Special types of munitions are used for training purposes (practice shells), the generation of screening smoke (smoke rounds) or battlefield illumination which usually contain no or very little amounts of explosives. To assure sustained illuminating or the ejection of sub-munitions at high air-burst points small parachutes are used to slow down special munitions in the end phase of trajectories.

a. Mortars

Mortars are light IFWS that consist of a tube, a robust baseplate and the mounting (bipod) with sight (optics) and aiming equipment which serves to set and fine-tune the direction and elevation of the barrel. The muzzle-loaded (mainly smooth-bore) barrel fires projectiles with a steep angle elevation of above 45° with the recoil power directed to the ground. Therefore, when in fire position it stands on a steel plate that is either fixed to the ground or mounted on a stable vehicle such as a lightly armoured tracked carrier with robust suspension.

If not integrated in an armoured carrier, the main parts of mortars have to be mounted before use and disassembled during movement. Light mortars such as the 81 mm L16 ML can be broken down to three man-portable loads each weighing approx. 12 kg while heavier mortars have to be transported on carriers. Munitions have to be carried separately. Given the weight of mortar parts and distinct functions to be performed simultaneously in fire position, during assembly, disassembly and movement, mortars are served by a crew including a commander and gunners who are responsible for aiming and firing, loading, preparing the selected rounds, fuses and charges and carrying them to the system in firing position.

Though these simple, light weight mortar systems are less accurate than artillery guns their production is cheap and their transport easy. Thus, mortars are available in all battlefields in large numbers and typically used for fire support of own infantry units in frontline positions. A number of militias in Syria and elsewhere produce mortars and munitions with low technical standards, significantly reduced performance and degraded accuracy and precision of delivery.

Heavy mortars of Soviet origin are still used in Eastern Europe and the Middle East. Given their high calibres and weight, they are moved on wheeled carriages towed by trucks. The extended length of barrels requires breech-loading. Such heavy systems complement the arsenals of artillery rather than that of infantry units.

Standard types of mortar systems in use in contemporary wars were produced during the Cold War and are mostly of Soviet, U.S.-American or European design. Most of them have either medium calibres of 81 mm or 82 mm with ranges between several hundred and 5,500 meters, or heavy calibres of 120 mm and above with ranges up to approx. 7,000 meters. Heavy mortars firing advanced munitions can reach up to approx. 9,000 meters.

Mortar system[61]	origin	calibre	crew	combat weight	max. range	max. range extended
81mm L16 ML	UK	81 mm	3+mun	36 kg	5,660 m	
81mm M29 A1	USA	81 mm	6	52 kg	4,700 m	
82mm 2B9 Vasilek	USSR	82 mm	6	632 kg	2,500 m	
M-1943 Samovar	USSR	120 mm	6	275 kg	5,700 m	7,000-9,000 PGM for
120mm Tampella	Finland[62]	120 mm	5-6	160 kg	6,350 m	120mm modifications
M-160 Heavy Mortar	USSR	160 mm	7	1,300 kg	8,040 m	
M-240 Heavy Mortar	USSR	240 mm	8	3,610 kg	9,700 m	(20 km RAP)

The technical design of mortars allows for short range fire out of and into defilades, e.g. against targets behind natural elevations and obstacles that cannot be engaged by direct fire weapon systems and IFWS with flatter trajectories. To that end, various types of rounds are used with a mixture of high-explosives (HE) and fragments (HE-FRAG) that are generated by bursting cases. Special rounds are designed to produce smoke screens or illuminate the battlefield. Light mortars of 81/82 mm calibre fire high explosive (HE) bombs weighing approx. 3-4 kg each with an explosive fill of 0.6-0.8 kg. The munition weight of medium 120 mm calibre mortars usually extend from 12 to 15 kg with an explosive fill between 2.0 and 2.6 kg. A heavy 160 mm mortar can fire 41.5 kg HE bombs at a fire rate of 2-3 rounds per minute.[63] The initial fire rate of an 81 mm L16 mortar is up to 15 rounds per minute.[64]

Area effects vary accordingly. The lethal radius around the impact of one 120 mm calibre HE mortar bomb is approx. 30 m with a 10 % probability of incapacitation at a distance of 100 m and a 10 % probability of suppression at a distance of 125 m.[65] The US Army estimates that at a distance of 80 m around the impact of an 81 mm mortar HE bomb and 100 m from the detonation point of a 120 mm mortar HE bomb 10 % of unprotected human beings would be incapacitated. Such risk would be reduced to 0.1 % at a distance of 175 m for 81 mm bombs and 400 m for 120 mm bombs.[66]

Mortars are typically used for fire support of own infantry units in frontline positions aiming at single and mass targets such as enemy combat forces and forward observation points or IFWS in firing position. To that end, combined mortar battery fire is concentrated on selected target areas to stop, suppress or neutralize combat troops and IFWS at short distances. Consequently, several mortars would fire simultaneously and at high fire rate onto the identified target area. E.g., when five mortars fire 3 rounds in short sequence, 15 bombs would impact in the target area. Consequently, the intended area effects would result from the direct effects of the impact of HE-FRAG bombs which are deliberately spread over a certain area combined with the technical imprecision of delivery and the inaccuracy of targeting.

[61] Cf. Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Warplanes, tanks, missiles, warships, artillery, small arms. Salamander Books Ltd., London 1985, p. 180-182; compare also D.M.O. Miller, William V. Kennedy, John Jordan, Douglas Richardson: East v. West. The Balance of Military Power. An illustrative assessment comparing the weapons and capabilities of NATO and the Warsaw Pact. Salamander Books Ltd., London 1981, p. 89

[62] Developed in Finland, based on a Soviet model, built in Israel and Germany. http://www.deutschesheer.de/portal/a/heer/start/technik/sonstig/moerser120mm/!ut/p/z1/hU69Dc accessed 05 October 2017

[63] Cf. S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 78; Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 181

[64] D.M.O. Miller, et alia: East v. West. The Balance of Military Power. Loc. cit., p. 89

[65] Cf. PAX / Article 36: Areas of harm. Loc. cit., p. 15

[66] Cf. S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 84

Imprecision of bomb trajectories results from small deviations from assumed standard conditions as to wind, air humidity, munition, charges and fuses. The CEP indicates the probability of 50 % of several rounds impacting within a certain distance to the aim point provided that the mortar is correctly aligned to the target. However, inaccuracy also results from a number of uncertainties within the targeting processes as to exact positioning, distances and traverse directions of targets relative to the firing positions. Furthermore, CEPs increase with growing distance. For a 120 mm cal. mortar HE bomb the following values are estimated for radii of impact around aim points without the use of advanced fire-control systems:[67]

Radius of impact area around aim point	at 2,000 m range	at 7,000m range	
50 % (1 CEP)	30 m	108 m	(136 m)
62 % (1.5 CEP)	44 m	160 m	
99 % (4.4 CEP)	132 m	480 m	

Such technical features and intended area effects result in tactical target areas (fire zones) for a mortar platoon of approx. 160 x 100 m or 200 x 200 m while reduced incapacitation effects can extend far beyond.

More accurate, advanced munitions are available in limited numbers and to modern armies only. E.g., the US army possesses the precision-guided mortar munition (PGMM) Type XM395 HE mortar projectile, a GPS-guided 120 mm calibre munition with a CEP of less than 10 m. Russia has developed the laser-guided variant for 120 mm mortars with a range of 7,000 m (smooth-bore tubes) or 9,000 m (rifled barrels). It can deliver a bomb containing 5.3 kg HE.[68] Due to their high cost (approx. 10,000 USD for each XM395) it is unlikely that PGM would replace conventional munitions in large numbers in the foreseeable future.

b. Field and self-propelled artillery

Field and self-propelled artillery belong to the medium and heavy IFWS that fire shells from tubes with wider ranges, more accuracy and precision and usually flatter trajectories than that of mortars. The rear-loaded, mainly rifled barrels are technically capable of elevations between approx. - 5 and + 70° and thus enable the guns to compensate for differences in altitude and local conditions of guns and target positions. Traverses of approx. 30° left and right or 360°, pending the gun carriage system, allow for quick changes of directions and, combined with long ranges and high sequence of firing, for engaging various targets in a wide target area at short time. The traverse position of the gun determines the direction of fire; the elevation of the barrel combined with the size and number of charges are the main parameters to determine the range of the shells – pending the firing position in relation to the location of the target. While the gun of a field artillery piece rests on a solid wheeled carriage that is towed by a truck, guns of self-propelled artillery are mounted on lightly armoured tracked or wheeled vehicles and, thus, are both more mobile and more protected.
The gun projectiles are usually propelled by separate charges out of the barrel. The recoil power resulting from such explosions causes the tube to jump backwards. A robust suspension system cushions and contains such jumps and causes the barrel to slide back in the initial position. Because of such movements the recoiling barrel is mobile-chambered within a rifled liner. The aiming equipment (gunsight) and mechanics which serves to set the direction and elevation of the barrel as well as loading systems are attached to the cradle on which the rifled liner with the barrel is mounted.

[67] Cf. PAX / Article 36: Areas of harm. loc. cit., p. 15, 16, 39, 40
[68] Cf. S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 39. NATO 120 mm HE mortar projectiles have a nominal CEP of approx. 136 m. Loc. cit., p. 34

Given the size and weight of rounds (see below) only a limited number of munitions, charges and fuses can be stored within self-propelled guns and even less so on towed pieces while most of the ammunition is transported on separate ammunition vehicles. To enable sustained fire over a longer period of time additional logistic units are required to ensure continuous ammunition supply. In light of simultaneous distinct functions to be carried out during movement, preparation of the fire position and fire fight, artillery systems are served by crews including a commander and gunners who are responsible for aiming and firing, loading and preparing the selected munitions.

The technical design of artillery howitzers and canons allows firing shells on medium ranges. Most of the artillery systems that are used by countries where ground-launched attacks have become a source for concern are howitzers with 105, 122, 152 or 155 mm calibre. They can cover ranges between 8 and 24 km. Advanced munitions and reinforced propellants such as Rocket Assisted Projectiles (RAP) can reach 30 km and more: [69]

Field artillery (Towed)	origin	calibre	crew	combat weight	max. range	max. range extended (RAP)
Light Gun	UK	105 mm	6	1,860 kg	17,200 m	
Howitzer D-30	USSR	122 mm	7	3,150 kg	15,300 m	21,900 m (RAP)
Gun-Howitzer D-20	USSR	152 mm	10	5,560 kg	24,000 m	37,000 m (RAP)
Howitzer M198	USA	155 mm	10	7,165 kg	22,000 m	30,000 m (RAP)
Gun 155mmTR	France	155 mm	8	10,650 kg	24,000 m	33,000 m (RAP)

Self-propelled Howitzers	origin	calibre	crew	combat weight	max. range	max. range extended (RAP)
M-1974 2S1	USSR	122 mm	4	16,000 kg	15,300 m	21,900 m (RAP)
M-1973 2S3	USSR	152 mm	6	23,000 kg	24,000 m	37,000 m (RAP)
152mm DANA	Czech	152 mm	6	23,000 kg	24,000 m	37,000 m (RAP)
155mm AMX-GCT	France	155 mm	4	42,000 kg	24,000 m	31,500 m (RAP)
M109 A2/A3	USA	155 mm	6	24,950 kg	18,000 m	24,000 m (RAP)
M110 A2	USA	203 mm	5 + 8	28,350 kg	24,300 m	30,000 m (RAP)
Panzerhaubitze 2000	Germany	155mm	5	57,000 kg	30,000 m	40,000 m(RAP)

Tube artillery can fire various categories of rounds pending calibres and types of weapon systems with a mixture of high-explosives and fragments that are generated by bursting cases. For special purposes practice, smoke and illumination shells are available. D-30 122 mm howitzers fire HE projectiles with a total mass of 21.8 kg containing approx. 20 % of high explosives. Artillery guns with 152 or 155 mm calibres usually deliver HE shells of approx. 43 - 47 kg weight. One HE shell for a 152 mm calibre gun (SP-howitzer 2S3 or towed D-20) weighs approx. 43.56 kg containing 7.8 kg high explosive fill (18 %). A US made 155 mm HE shell (mod. M795) weighs 46.9 kg with an explosive fill of 10.79 kg (23 %).[70]

[69] Cf. Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 144-155; compare also D.M.O. Miller, et al.: East v. West. The Balance of Military Power. Loc. cit., p. 70-75; see also http://www.military-today.com/artillery/d20.htm; http://www.military-today.com/artillery/2s3_akatsiya.htm

[70] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 81; See also http://www.military-today.com/artillery/d20.htm; http://www.military-today.com/artillery/2s3_akatsiya.htm

The ground detonation of a typical 155 mm HE projectile causes a lethal area for unprotected human beings due to fragmentation within a radius of 25 m and injuries within a radius of 40 m. However, dispersed fragments fly much further and can still cause injuries at a distance of 550 m. The US Army estimates that at a distance of 125 m from the point of impact 10 % of unprotected human beings would be incapacitated and the risk would be reduced to 0.1 % at a distance of 450 m.[71]

Artillery is used as a flexible means to deliver fire support to combat troops or engage targets at long distances aiming at single and mass targets such as enemy combat forces, observation points, IFWS in firing position, advancing reinforcements and closing gaps in front of key terrain. Combined battery fire is concentrated on selected target areas to stop, suppress or neutralize combat troops, IFWS and logistical supply at medium and long distances. To that end, artillery batteries and groups concentrate fire onto the identified target area and fire simultaneously. To achieve a maximum surprise effect, several rounds are fired by each gun with maximum fire rate followed by fire with slower sequences. E.g., if 6 guns fire 3 - 4 rounds each in short sequence, 18 - 24 shells would impact in a target area of approx. 200 x 300 m within one minute while reduced incapacitation effects are felt far beyond. Soviet trained armies in the Middle East still follow Soviet Cold War doctrines according to which artillery groups have to be amassed in the centres of gravity.[72]

As in the case of mortars, the intended area effects would result from the direct effects of the impact of HE-FRAG shells which are deliberately spread over a certain target area combined with the technical imprecision of delivery and inaccuracies of targeting. Again, imprecision of trajectories results from deviations from assumed standard conditions as to wind, air humidity, munition, charges and fuses. The CEP indicates the probability of impacts of a number of rounds within a certain distance to the aim point provided that the gun is correctly aligned to the target. However, inaccuracy also results from a number of uncertainties within the targeting processes as to exact positioning, distances and traverse directions of targets relative to the firing positions. Also the recoil of the guns impacts on the exact position of guns. Therefore, fine-tuning of the direction and elevation of the tube might be required before the next shot can be fired without losing accuracy. Furthermore, CEPs increase with growing distance as the following example of 155 mm artillery guns demonstrate (generic values):[73]

Range	15 km	20 km	25 km	30 km
CEP	95 m	115 m	140 m	275 m

As opposed to area fire, the expensive terminal-phase guided munitions for precision fire against single point targets are available only in the inventories of advanced armies and in limited numbers. Thus, fuses with course correction capability such as the US XM1156 Precision Guidance Kit are designed to reduce the CEP of conventional 155 mm artillery munitions to 50 m or less.[74] Special precision-guided munition (PGM) such as the “Copperhead” munitions for 155 mm guns were developed already at the end of the Cold War for use against armoured follow-on echelons.

The “Copperhead” projectile was stabilized by wing and tale control fins after it had left the gun barrel and fitted with a homing device which was activated at the apogee of the trajectory. It

[71] Loc. cit., p. 60, 84

[72] According to Soviet Cold War doctrine up to 1,000 mortars, tube artillery and multiple-barrel rocket launchers had to be amassed against target areas of 3,000 m width to enable combat troops to break through the main enemy defences.

[73] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 34

[74] Loc. cit., p. 39

followed a laser energy beam spotted on the target by “laser target designators” operated by forward artillery observers, observation aircraft or special operation forces. The “Copperhead” projectile could manoeuvre to seek out a moving target such as an armoured vehicle within a circle of 3,000 m as long as the laser beam continued to illuminate the target.[75] However, bad weather conditions, battlefield smoke and fog, obstacles like vegetation and buildings as well as enemy counter-measures directed at laser target designators can interrupt the laser beam and lead to failure. While this example shows a revolutionary improvement of targeting precision, it also demonstrates the limitation of PGMs pending battlefield conditions.

In contrast, most forces use elder types of armaments that are designed to deliver massive area fire within a short time such as interdiction, neutralization and counterbattery fire or to hold the enemy at risk by sustained opportunity and sweeping fire at low fire rates.

According to Russian and former Soviet doctrine which is still observed in several armies in Eastern Europe and the Middle East, tube artillery can also be employed in an anti-tank role at short distances using direct (line of sight) targeting. To that end, e.g., the D-30 122 mm howitzer fires a fin-stabilized non-rotating HEAT (high explosive anti-tank) shell at distances of approx. 1,000 m thus producing a formidable direct fire capability against armour.[76] A D-20 152 mm HE shell penetrates a 250 mm steel plate at 3,000 m range.[77] Such capabilities can also be used in urban terrain to eliminate targets by destroying their wall protections. Intensive use of such tactics can lead to destruction of residential areas, industrial structures and public buildings. On the other hand, it increases the vulnerability of artillery by exposing it to direct counter-fire.

c. Multiple-barrel rocket launchers (MBRL)

Multiple-barrel rocket launchers (MBRL) fire unguided rockets from a number of parallel-installed tubes that are either mounted on a towed carriage or carried by a truck or a lightly protected (tracked or wheeled) armoured vehicle. Since the rocket engines propel the rocket from tubes that are open on both sides only little recoil power is generated. The typical use is firing salvos from a number of tubes or all tubes in short sequence, i.e. in several seconds. Afterwards, the tubes have to be reloaded which might take 15 to 30 minutes pending the system. Generally, the operation of MBRL needs less personnel than field artillery. However, munitions for reloading have to be transported on separate vehicles that accompany the MBRL.

Medium MBRL with 122-140 mm calibres cover ranges of 10 - 20 km, heavy MBRL with 220-300 mm calibres more than 30 km, and advanced systems even 70 - 90 km[78]:

MBRL	carriage	origin	calibre	tubes	crew	weight	max. range
RPU-14	towed trailer	USSR	140 mm	16	7	7,000 kg	10,000 m
BM-24	truck-mounted	USSR	240 mm	12	*6*	*10,000 kg*	17,500 m
BM-21	truck-mounted	USSR	122 mm	40	3	13,700 kg	20,000+ m
RM-70	truck-mounted	Czech	122 mm	40	6	33,700 kg	20,400 m
MLRS I	self-propelled	US/German	227 mm	2 x 6	3	21,000 kg	38,500 m
MLRS II	self-propelled	US/German	227 mm	2 x 6	3	26,000 kg	84,000 m
BM-27 Uragan	truck-mount	Russia	220 mm	16	4	22,700 kg	34,000 m

[75] D.M.O. Miller, et alia: East v. West. The Balance of Military Power. Loc. cit., p. 72

[76] Cf. R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 154

[77] http://www.military-today.com/artillery/d20.htm

[78] Loc. cit., p. 165-167; D. Miller, et al., East v. West. The Balance of Military Power. Loc. cit., p. 69, 72; http://www.military-today.com/artillery/bm27_uragan.htm; http://www.military-today.com/artillery/smerch.htm; http://www.military.com/equipment/m270-multiple-lauch-rocket-system; http://www.kmweg.de/home/artillerie/raketenwerfer/mars-ii/produktinformation.html

BM-30 Smerch truck-mount	Russia	300 mm	12	4	43,700 kg	70,000 - 90,000 m

Pending the types and calibres of MBLR, rocket warheads contain various amounts of high explosives (HE) and fragmentation. E.g., a BM-21 (mod. 9M22) rocket weighs approx. 45.9 kg. The 19 kg warhead contains 6.4 kg of HE composition. It can generate almost 4,000 fragments from scored diamond patterns inside the munition casing representing a total mass of approx. 15.3 kg. Additional non-controlled fragments from materials hit by the warhead (approx. 1.5 kg) would increase the number of designed fragments. In consequence, the ground impact of one single warhead would cover a lethal area of 700 m² equal to a radius of approx. 15 m.[79] Different points of detonations such as proximity bursts, pending the setting of time or proximity fuses, would tailor the impact to intended effects.

A single BM-21 can fire a salvo of 40 rockets within less than 30 seconds. In that case, it would deliver an amount of 256 kg HE composition and approx. 612 kg of designed fragments and generate approx. 60 kg of additional natural fragmentation covering an area of 600 x 600 m.[80] The size of the area (rather an ellipse) in which the rockets come down increases with range and quantity of rockets fired. E.g., 46 % of rockets fired by a BM-21 salvo at long-range (19 km) are likely to impact in a rectangle area of approx. 560 m x 315 m.[81]

Such large MBLR CEPs mainly result from the design of rockets and delayed boost phases which allow traverse winds to influence rocket trajectories more than artillery shells. Also tip-off due to launcher motion causes certain deviations.[82] Assuming a battery of 6 BM-21 systems fires full salvos simultaneously, either the density of fragments or the size of the impact area would increase accordingly. The lethal area might well cover 1,200 x 900 m.

Heavy MBLR systems have increased ranges and can cover wider impact areas. A BM-27 220 mm rocket weighs 280.4 kg with a warhead of 90-100 kg. A full salvo of 16 rockets would cover an area of approx. 600 x 600 m. The weight of a BM-30 300 mm rocket is approx. 800 kg and contains a warhead of 240-280 kg. A full salvo of 12 rockets with sub-munitions can cover an area of up to 800 x 800 m.

Generally, MBRL are designed to bring down a maximum amount of heavy fire on a wide target area within 10 to 40 seconds. The military purpose behind such massive and rapid area fire is achieving a maximum impact on enemy mass targets at decisive moments in high-intensity battles, such as stopping a massive offensive operation geared to break through own defences or supporting own advances in the centres of gravity.

Modern MBLR with advanced fire control systems and munitions are capable of delivering more precise and accurate fire at long ranges by use of terminal-phase guided rockets with precise armour-piercing munitions or anti-tank mines. Advanced MBRL systems can combine both capabilities. E.g., the U.S./European-made 227 mm MLRS (M270/MARS) can fire 12 rockets with a full combat weight of 272 kg each. Every rocket can carry sub-munitions that can disperse over an

[79] Samuel Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Final Report. GICHD, Geneva, February 2017, p. 52 – 56. The report notes that the probability of incapacitation would reduce with growing distance from the point of impact: 96 % at 3m, 64 % at 10 m, 36 % at 15 m and 17 % at 20 m distance. Loc. cit., p. 56. Note that for the model 9M22U a total munition weight of 66.6 kg is given on p. 81 while the explosive weight of 6.4 kg does not change.

[80] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 53

[81] Cf. PAX / Article 36: Areas of harm. loc. cit., p. 19, 41

[82] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 32

area of approx. 100 x 220 m.[83] An integrated fire-control system and end-phase homing allow for reduced CEPs. Advanced versions such as the ER-MLRS (MARS II) are able to deliver highly precise guided missiles against single point targets with a CEP of approx. 7 m at ranges between 70 and 100 km. A modified version of the MLRS system can also accommodate one or two U.S. Army Tactical Missile System (MGM-140 ATACMS) which can reach targets at ranges of more than 300 km with high precision.[84]

Such modern systems might change the typical characteristics of MBRL in future. In contemporary wars, however, elder MBRL mainly of Soviet origin are used predominantly for area covering surprise shelling to accelerate the attrition of enemy forces. In this context, irregular forces also use self-produced MBRL of simple design ("*hell canons*") that are even less accurate and precise than professionally produced MBRL. Mounting them on lightweight civilian pickup trucks adds to instability of delivery and increases imprecision and inaccuracy.

As MBRL are designed for rapid suppression and attrition of mass targets in large areas it is obvious that such systems, in particular those of elder design without precise targeting capabilities, are generally not suited for engaging point targets in populated areas but pose high risks to an unprotected civilian population left in areas of combat.

2.3.2 Accuracy of IFWS targeting

Although direct (line of sight) firing at point target is possible at close range for howitzers and even more so for canons, IFWS are generally used in an indirect mode of firing to engage targets beyond the direct line of sight over wide ranges. Central firing positions behind frontlines allow quick changes of target areas within a wide radius and, at the same time, keep IFWS outside the impact of enemy direct fire weapons. The indirect targeting mode also allows to fire from hidden positions behind hills, forest or other obstacles and strike on protected targets behind natural elevations, buildings and walls or in field fortifications, entrenchments, and shelters which cannot be engaged by direct line of sight fire.

a. Weather conditions, testing and training

As discussed above, modes of delivery, far ranges and high ballistic trajectories of IFWS imply inherent imprecisions. Generally, the precision of calculated impact points of mortar bombs, artillery shells and rockets reduce as ranges increase. Weather conditions such as temperature, air humidity, wind strength and direction, and their impact on different types of munitions, but also material differences and modifications in manufacture of various models cause deviations from projected ideal trajectories. Given such inherent imprecisions of indirect targeting special techniques, forward observation and assisting means are needed to reduce such deviations as much as possible.

Regular weather observation and thorough testing are required to establish data bases and calculation tables for different munition types, charges, weather conditions, and ranges. Intensive training and life firing practice are needed to ensure that the involved personnel, in particular the fire control officers, are in a position to work efficiently and precisely with such tables. Automated firing control systems – if fed with correct data - greatly improve quick calculation of target positions, weather conditions, types of ammunition, number of charges, set of fuses, direction and elevation of the tubes, etc.

[83] Cf. Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 167; Christy Campbell (Ed.), Understanding Military Technology. Hamlyn London, 1985, p. 80

[84] http://222.military-today.com/missiles/atacms.htm

b. Forward (line of sight) observation and impact control

Forward artillery observation teams spot targets at direct lines of sight and communicate via radio or data link to IFWS in rear fire positions, often several kilometres behind frontlines. They guide the fire by describing the nature of the target to be engaged, the own position, the estimated geographical position of the target, and the desired impact to be achieved which determines the type and number of rounds needed. Laser meters allow the precise determination of ranges to the target.

Registration fire is a usual mode of correcting the accuracy of impact if time allows. Since the first shot fired is likely to impact further away from the medium aim point, forward observers call for two or three single (test) shots first, locate the point of impact relative to the main aim point and convey the result to the fire control officer for corrections. By repetition forward observers fine-tune the delivery and move the fire into the centre of the target before concentrated battery fire is released. With that method the impact points of mortar bombs and artillery shells can be “walked” towards the medium aim point. In defence, such registration fire can be prepared ahead of enemy advances if pre-planned barrages would aim at closing gaps and approaches towards own forward positions or key terrain. However, this procedure cannot be applied if the engagement of short-time opportunity targets (e.g. moving columns) requires immediate action with full fire power.

Forward observation at sight is limited in range and depends on the battlefield conditions. It might be hampered by terrain features, confined to daylight and suitable visual conditions if appropriate observation tools (night googles, infra-red search lights, laser etc.) are not available, and is subject to interference by enemy fire or obscuring smoke screens. Extended forward observation might be possible if salient observation points such as mountains or high buildings allow for remote or hidden target observation. Also reconnaissance patrols penetrating enemy lines are a means to guide fire at targets deep in the rear of enemy positions.

c. Technical target acquisition

If the targets are outside the line of sight of forward observers, technical target acquisition means might guide the targeting if available. E.g., in order to detect enemy artillery systems in rear firing positions sound and optical sensors are deployed for *flash and sound ranging* of gun bursts. However, such measurements (in particular flash ranging) are not exact – pending the number and geographical positions of sensors – and will determine an area rather than a point.

Artillery *radar systems* trace high angle trajectories of shells fired by enemy IFWS such as mortars or howitzers and calculate their firing positions. Combined with modern fire control systems that allow fast data processing such sensors might enable quick counterbattery fire of own IFWS to destroy enemy systems before they change their positions.

Electronic measurement of *radio communication* can be used to detect command and control centres though with limited geographical precision. For more accurate IFWS targeting, usually further tracking by other means is necessary.

Air reconnaissance is carried out by aircraft or helicopters equipped with optical, infrared and digital cameras or radar sensors. They provide situation reports and imagery for areas beyond ground observation including geolocation of target positions. Such information can be used for far-ranging tube and rocket artillery. However, air reconnaissance is confined to a low number of sorties per aircraft per day and a short lingering time in the area under observation. The time delay between target reconnaissance, evaluation of acquired data, mission order and weapon delivery might cause problems, particularly in a fluid and highly mobile battle, as targets might move away or undetected civilians move in. Automated assessment and targeting processes combined with direct communication links between aircraft and fire control centres can shorten the response time.

The employment of *Remotely-piloted* or *Unmanned Aerial Vehicles* (RPV, UAV, “drones”) enable more sustained observation of wide target areas either through repetitive overflights or loitering over the target area. UAVs can carry optical and infrared cameras as well as radar sensors and laser designators. Specifications, range and operation hours vary pending sizes and models. Direct data links to fire control centres allow quick reaction of IFWS provided that ranges and trajectories of artillery systems match with the positions of targets.
However, UAVs are not invulnerable. Their sustained use depends on enemy short and medium range anti-air and electronic jamming capabilities.

d. Pre-planned and map firing
For cases in which forward observation is not possible or cannot be applied quickly enough to be effective, artillery also prepares and uses pre-planned fire zones at tactically important locations such as river banks, bridges, railways, cross-roads, communication hubs, logistical depots or command and control centres. The purpose is to protect key terrain, prevent or stop enemy surprise assaults against own defences, hamper advances of reserves towards the frontline or destroy logistical, command, control and communication capabilities.

In these cases, the impact of indirect fire is calculated according to map coordinates. Fire against such pre-planned fire zones has targeting priority and is executed immediately on order once critical enemy movements are detected or imminent. Generally, map firing is less accurate than observed firing. However, if the situation, the available time and a direct line of sight of forward observers permit, such tasks are tested before the enemy closes in. To that end, single test rounds are fired to enhance the precision of salvos.

e. Accuracy and reliability of targeting
Computer-based fire control systems (FCS) have greatly improved the accuracy of targeting and, to a large extent, replaced fire tables and manual calculations in modern armies. Based on acquired data on weather conditions, enemy positions and types of targets such modern FCS calculate automatically trajectories for suitable munitions, necessary charges and fuses, and define appropriate elevations and directions of tubes in firing position. Thus, fire control officers dispose at a valuable tool enabling them to react much quicker, more precisely and with tailored munitions to reduce area effects.

Although modern fire control systems have greatly improved the accuracy and responsiveness of targeting, their reliability depends on the target data acquired by visual or technical observation. Failed description by intelligence and observation of positions, nature and size of targets or their expected direction of movements lead to misses and failures in achieving the intended military effects. At the same time, it might cause unintended collateral damage. In this context, all targeting acquisition and location methods discussed above have their tactical values while their accuracy varies. Under battlefield conditions they can fail as they are subject to enemy counter-measures and frictions which are no exceptions but the normalcy in war.

This is also true for precision-guided munitions (PGM) such as terminal-phase guided bombs and sub-munitions or guided missiles. Such use of PGM can significantly reduce CEPs and diminish collateral damage when directed against single point targets provided the direct munition effects are tailored to small areas and the guiding sensors can operate without interference. However, most regular and, certainly, irregular forces in contemporary wars do not hold such modern targeting equipment, reliable delivery means and precise munitions in their inventories.

After all, IFWS have been developed for two main purposes: fighting targets which are protected by hardened structures or natural obstacles without exposing own troops to direct fire, and engaging simultaneously mass targets that are deployed in wide areas.

2.4 Ground-launched direct fire weapon systems (DFWS)

2.4.1 Delivery systems, munitions, effects

Direct fire weapon systems (DFWS) deliver projectiles from barrels and anti-tank guided missiles from light launchers over short effective ranges between several hundred meters and a maximum of 4,000 m – depending on the system used. As DFWS aim directly at the target, trajectories of projectiles and missiles follow closely the line of sight. They can engage fixed and mobile, armoured and soft enemy targets at distances within visual range and significantly more precisely and accurately than IFWS. A number of DFWS are capable of destroying armour and other protections such as stone walls and above surface field fortifications. To achieve the desired effects projectiles either bring to bear high kinetic energy or high explosives that burst on impact.
DFWS are composed of the following sub-categories:

- Heavily armoured main battle tanks with canons of 90 to 125 mm calibre fire kinetic energy and explosive rounds up to an effective range of 4,000 m. Light tanks have guns with smaller calibres of 76 to 105 mm and engage targets at shorter effective ranges.
- Towed and self-propelled anti-tank guns fire explosive rounds with calibres between 76 and 100 mm up to an effective range of approx. 1,500 m.
- Light (machine) cannons of 20 - 50 mm calibre can fire both explosive rounds and kinetic energy ammunition with high fire rates up to an effective range of 2,000 m. They can be mounted on armoured combat vehicles, trucks or towed carriages.
- Anti-tank guided weapon systems (ATGW) fire guided missiles from light launchers which are either man-portable or mounted on armoured combat vehicles or trucks. They engage predominantly tanks and armoured vehicles with high explosive (shaped-charge) warheads at effective ranges between 2,000 and 4,000 m.

"*Effective range*" means the maximum distance at which the weapon system firing a projectile in combat would achieve the military purpose by engaging the target with an acceptable hit and incapacitation probability, i.e. sufficient accuracy and inflicted damage. However, projectiles missing the target can travel at their "*maximum ranges*" exceeding the "*effective ranges*" by far if not impeded by natural elevations or buildings and other artificial structures. E.g., a 30F18 HE-FRAG projectile fired from a Soviet-made 115 mm 2A20 Molot tank gun at an angle of 16° can reach a maximum range of 9,500 m.[85]

Explosive projectiles are propelled through rifled or smooth-bore gun barrels by charges that are either separately loaded or integrated in munition cases. The empty cases are ejected when the projectiles are fired. While rifled barrels cause projectiles to rotate along their length axes in order to stabilize trajectories, non-rotating projectiles are fin-stabilized and mainly fired from smooth-bore barrels.

Explosive Projectiles and anti-tank missile warheads contain different types of armour-piercing high explosives (HEP/HESH/HEAT) or high explosives (HE), often mixed with metal fragments (HE-FRAG). Usually, such munitions explode on impact while some are reinforced with resonators

[85] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 22, 23

that cause explosions in short sequence to penetrate armour. Munitions fired by tank barrels use two methods of attacking heavy armour, either by applying chemical energy of high explosives or relying on kinetic energy of solid mass / high velocity projectiles:

High-explosive plastic (HEP) or squash-head (HESH) shells have frangible nose cones, explosive charges and base fuses. While the nose cones break up on impact, explosive charges splatter against the surface of the armour with the base fuses detonating them. The shock waves, which are transmitted through the armour and reflected by the inner plate, trigger scabs being detached from the inside and ricocheting in the vehicle. [86]

“Hollow charge” high-explosive anti-tank (HEAT) shells have proven a more effective alternative. They have hollow nose cones and explosive charges formed with a convex cone. On detonation of the base fuse, the cone focuses the gases into a fine jet which is projected forward to burn through the armour and into the tank interior.[87]

Kinetic energy anti-tank projectiles such as the armour-piercing discarding sabot (APDS) rounds rely on the penetrative ability of a solid mass rather than high-explosive energy. High velocity and small solid mass with high specific gravity are crucial to achieve a more stable trajectory and the necessary focused energy-to-mass balance resulting in high precision and penetration power. Sub-calibre solid penetrators are made of tungsten or depleted uranium.[88] Special light-weight “sleeves” enclosing the penetrator fill out the barrel calibre and help the propellant charges to concentrate energy in the high-density penetrator. Smoothbore guns firing fin-stabilized projectiles (APFSDS) increase muzzle velocities and enable to deliver larger masses with higher penetration capability and first-shot kill probability though with marginally less accuracy and effective ranges than rifled barrels.[89]

HEP/HESH and HEAT projectiles have several shortcomings as their effectiveness can be degraded by surface obstacles which cause the explosives to detonate prematurely or spread in various unintended angles. E.g., spaced armour can trigger HEP/HESH detonations before reaching the inner armour of tanks. The effectiveness of HEAT depends on the diameter of hollow charges. A HEAT shell of over 76mm calibre is likely to penetrate any conventional armour and, with added resonators behind the charge, to penetrate spaced armour. However, the introduction of compound, composite (Chobham) and explosive reactive armour (ERA) for most modern heavy main battle tanks (MBT) has degraded or neutralized the effectiveness of HEAT shells. Therefore, the expensive kinetic energy munitions have become the primary means of modern armies to engage enemy tanks. E.g., a modern tank such as the Leopard 2 with a 120 mm Rheinmetall L55 gun firing APFSDS DM 53 rounds can penetrate all advanced standard heavy tanks at a range of well over 2,200 m.[90]

For all other purposes, however, high explosive munitions have remained valuable assets and are widely in use such as HE/HE-FRAG projectiles fired against moving infantry, transport and lightly

[86] Christy Campbell (Ed.), Understanding Military Technology. Hamlyn London, 1985, p. 97; see also Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 132

[87] C. Campbell (Ed.), Understanding Military Technology. Loc. cit., p. 98

[88] The negative and long-term hazards posed by the use of depleted uranium munitions to human beings and the environment are not subject to this paper but should be noted though. Cf. United Nations General Assembly Resolution adopted on 5 December 2016 entitled “*Effects of the use of armaments and ammunitions containing depleted uranium*.” (A/RES/71/70 of 14 December 2016)

[89] C. Campbell (Ed.), Understanding Military Technology. Loc. cit., p. 97

[90] Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 135; http://www.military-today.com/tanks/leopard_2.htm

armoured vehicles or targets protected by walls and surface field fortifications. Their immediate area effects are similar to those of artillery shells of equal calibres. E.g., the detonation of a tank gun IM HE-T 120 mm calibre projectile would result in a lethal area within a radius of approx. 25 m around the point of impact and still have a 10 % probability of incapacitation at a distance of 90 m. The immediate effects of the detonation of the projectile are likely to be reinforced by natural fragments or splinters of the target engaged. Only at a distance of 250 m would the probability of incapacitation be reduced to 0.1 %.[91]

Although direct targeting is generally more accurate and precise than that of IFWS (except for PGMs) the unintended effects of misses should not be underestimated. If the target is not hit within the *effective* ranges of DFWS, munitions would fly up to their *maximum* ranges or impact on the next natural or artificial surface obstacle within trajectories. Such incalculable random impact can cause severe unintended collateral damage, in particular in urban terrain.

a. Main Battle Tanks (MBT)

Main battle tanks (MBT) are heavily armoured and highly mobile vehicles that carry guns of 90 - 125 mm calibres which are mounted in turrets that can be traversed through a full 360°.[92] They fire kinetic energy and explosive rounds (HE, HE-FRAG, HEP, HESH, HEAT) up to an effective range of approx. 1,500 - 3,000 m pending types and models. Some tank guns are capable of firing anti-tank guided missiles at ranges of up to 5,000 m. Tank guns are usually capable of an elevation of up to 20° and a depression of up to 10° to compensate for differences in tank and target positions. Large calibre canons, heavy armour, powerful engines and agile cross-country mobility require stable, mostly tracked vehicles with robust suspension weighing between 45 and 60 tons. MBT are usually operated by a crew of 4 – a commander, a gunner, a driver and a loader who often also operates radio communications. Lighter wheeled tanks have higher road speed and are in use where acceptable road and terrain conditions allow their deployment. MBT are fitted with machine guns (coaxial and anti-air) and smoke dischargers to screen their exact position while in motion under attack.

Main battle tanks (MBT) are the most powerful battlefield systems combining heavy fire power and fast cross-country mobility under high intensity battle conditions by providing robust armoured protection against enemy fire. They are a main element of mobile, combined arms battles, often used in an offensive role. Therefore, they are found in current inventories of almost all armies worldwide and have been widely used in past and contemporary battlefields including by irregular forces. Most of the MBT in use are of Soviet (or Russian and Ukrainian), U.S., UK, French, German, Swedish and Israeli origin. Also Japan, China, India, Iran, Argentina and other states produce tanks, largely based on Soviet or U.S. models which were modified and further developed.

The following examples of models which are partially still in use give estimated average values while various modifications can have enhanced performances as to reinforced armour, road speed, cross-country mobility, agility, fire control systems, automatic loaders, etc.:[93]

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[91] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 84

[92] The CFE Treaty, Art. II 1. (C) defines battle tanks as *"… tracked armoured fighting vehicles which weigh at least 16.5 metric tonnes unladen weight and which are armed with a 360-degree traverse gun of at least 75 millimetres calibre. In addition, any wheeled armoured fighting vehicles entering into service which meet all the other criteria stated above shall also be deemed battle tanks*." Treaty on Conventional Armed Forces in Europe of 19 November 1990 www.osce.org/library/14087?download=true

[93] Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 130 – 140; D. Miller, et al., East v. West. The Balance of Military Power. Loc. cit., p. 57, 59, 61. http://www.military-today.com/tanks/leopard.htm http://www.military-today.com/tanks/amx_30.htm http://www.military-today.com/tanks/leclerc.htm; http://www.tanks-encyclopedia.com/coldwar/USSR/soviet_t-64.php;

Type	origin	weight	main gun/eff. Range (m)	machine-guns
T-54/55	USSR	36,000 kg	100 mm/1,500	7.62 mm (coax), 12.7 mm
T-64	USSR	38,000 kg	125 mm/2,000	7.62 mm (coax), 12.7 mm
T-72	USSR	42,000 kg	125 mm/2,000	7.62 mm (coax), 12.7 mm
T-80	USSR	44,000 kg	125 mm/2,500+	7.62 mm (coax), 12.7 mm
Merkava Mk3	Israel	60,000 kg	120 mm/2,500+	ATGM LAHAT, 60mm mortar, 3x7,62
M-48 A1-5	U.S.	49,000 kg	105 mm/1,600	7.62 mm (coax), 12.7 mm AA
M-60 A3	U.S.	52,600 kg	105 mm/2,000	7.62 mm (coax), 12.7 mm AA
M-1	U.S.	54,400 kg	105 mm/2,000	7.62 mm (coax), 12.7+7.62mm AA
M-1 A2	U.S.	65,000 kg	120 mm/2,500+	7.62 mm (coax), 12.7+7.62mm AA
Challenger	UK	62,000 kg	105 mm/2,000+	7.62 mm (coax), 7.62 mm AA
Challenger 2	UK	62,500 kg	120 mm/2,500+	7.62 mm (coax), 7.62 mm AA
AMX-30	France	37,000 kg	105 mm/2,000	20mm or 12.7mm (coax), 7.62 mm
Leclerc	France	54,600 kg	120 mm/2,500+	7.62 mm (coax), 7.62 mm AA
Leopard 1A4	Germany	42,200 kg	105 mm/2,000	7.62 mm (coax), 7.62 mm AA
Leopard 2	Germany	55,000 kg	120 mm/2,500+	7.62 mm (coax), 7.62 mm AA

Some armies and irregular forces in Middle East wars also use tanks mainly for static fire support roles instead of conducting mobile operations. To that end, they even apply indirect artillery targeting methods. Such employments were foreseen as a secondary role in earlier Soviet doctrines geared to support defensive operations. Given comparable gun calibres and munitions, the immediate detonation effects of explosive projectiles resemble those of artillery while the precision of delivery and targeting accuracy of such use of battle tanks might be lower.

An AMX-30 105 mm HEAT round weighs 22 kg and can penetrate 360 mm of armour at an angle of 0°. A 105 mm APFSDS projectile can still penetrate 50 mm armour at an angle of 60° and a range of 5,000 m. [94] 115 mm and 120 mm calibre HE projectiles weigh 16-18 kg and contain approx. 3 kg of explosive fill (16-20 %). 125 mm HE projectiles weigh 23-34 kg and contain approx. 3.2-4 kg.[95] The detonation of a tank gun IM HE-T 120 mm calibre projectile would cause a lethal area around the point of impact with a radius of approx. 25 m and a 10 % probability of incapacitation at a distance of 90 m.[96]

b. Light tanks, tank destroyers, anti-tank guns

Light tanks have guns with smaller calibres such as 76, 85 or 90 mm (occasionally also 105 mm) and engage targets at shorter effective ranges. They are either tracked or wheeled and often used for quick deployment in less intensive battlefield scenarios, against lightly equipped adversaries, for battlefield reconnaissance or direct fire support of infantry units. Special tank destroyers (self-propelled) were developed for defensive operations against attacking MBTs. They are usually operated by crews of 3-4.[97]

Towed anti-tank guns play a similar role in countering attacking MBTs from defensive positions. They are still in use in Eastern Europe and Middle East armies but – like tank-destroyers - cannot be found any more in the arsenals of modern western armies. Anti-tank guns with larger calibres can

http://www.tanks-encyclopedia.com/coldwar/USSR/soviet_t-72.php; http://www.tanks-encyclopedia.com/coldwar/USSR/soviet_t-80.php

[94] Ray Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 130

[95] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 82, 83

[96] ibid., p. 35

[97] The CFE Treaty Art. II 1. (D) defines armoured vehicles with integral/organic direct fire guns of at least 75 mm cal. and a weight of at least 6.0 metric tonnes as “heavy armoured combat vehicles”. Loc. cit. (Fn 92)

also be used as light artillery in an indirect fire support role, i.e. with high trajectories and an indirect mode of targeting. E.g., a T-12 anti-tank gun can fire a 100 mm calibre HE-FRAG round with a projectile weight of 17.6 kg at a range of 8,200 m.[98]
Light tanks, tank destroyers and towed anti-tank guns fire HE, HEP, HESH and HEAT projectiles with calibres between 76 and 105 mm up to an *effective* range of approx. 1,500-2,500 m. The immediate detonation effects are similar to those of MBT guns although their armour-piercing capabilities are lower and the lethal areas of HE rounds smaller. A 73 mm low-pressure smooth bore gun is mounted on the armoured infantry combat vehicle BMP-1 (see below, sub-section c.) of Soviet origin. It fires eight fin-stabilized HEAT rounds per minute with an automatic loading system.[99]

A number of the following examples of light tanks, tank destroyers and towed anti-tank guns[100] are still in use in Eastern Europe, the U.S. and the Middle East:

Type	origin	weight	main gun	machine-guns
ASU 85	USSR	15,500 kg	SD-44 85mm	7.62 mm (coax), 12.7 mm AA
AMX-13	France	15,000 kg	75 mm/90 mm	7,62 mm (coax), 7,62 mm AA
JPz 4-5	Germany	27,500 kg	90 mm	7.62 mm (coax), 7.62 mm AA
SK-105	Austria	17,500 kg	105 mm	7.62 mm (coax)
AMX-10RC	France	15,800 kg	105 mm	7.62 mm (coax)
Stryker MGS M1128	USA	21,000 kg	105 mm	7.62 mm (coax)
T-12 (towed)	USSR/Russia	2,750 kg	100 mm	(3,000-5,000 m range)

c. Light (machine) cannons (ACV and truck-mounted or towed)

Light (machine) cannons of 20 - 30 mm calibre are automated weapons that can fire both explosive rounds and kinetic energy ammunition with high fire rates at effective ranges of 1,500 -3000 m. They are mainly used for complementing firepower in combined armoured offensive operations, for direct fire support of dismounted infantry or for surprise encounters at reconnaissance missions. Also twin- and quadruple-canons exist which were originally designed for short-range air-defence (SHORAD) but are also used against ground targets.

Light (machine) cannons are usually mounted on tracked or wheeled armoured infantry fighting vehicles (AIFVs)[101], armoured reconnaissance vehicles (ARecV), lightly armoured fire support vehicles specially designed for light (mountain, airborne) infantry, and short-air defence systems (SHORAD). They can also be mounted on trucks or towed trailers.

Machine cannons are typically fired by bursts which influence the exact direction of weapons and degrade aim-target matching. Therefore, the impact of several rounds fired in fast sequence often scatters significantly around the main aim point. However, such scattering is intended to cover a wider target area such as the surface of enemy armoured vehicles, snipers using camouflage or building walls as protection to blur their exact positions, mass targets such as dismounted infantry

[98] http://www.wow.com/wiki/T-12_antitank_gun
[99] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 172
[100] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 149, 150, 152, 178; http://www.military-today.com/artillery/amx_10_rc.htm; https://www.militaryfactory.com/armor/detail.asp?armor_id=175 ; https://de.wikipedia.org/wiki/Stryker_Armored_Vehicle
[101] The CFE Treaty Art. II 1. (D) defines AIFVs as armoured combat vehicles which are fitted with an integral/organic canon of at least 20 mm cal., sometimes also an ATGW, if they can transport an infantry squad and normally provide fighting capability from inside the vehicle. Loc. cit. (Fn 92)

or low flying air targets. E.g., the self-propelled SHORAD system ZSU-23-4 can fire 57 rounds per second from a quadruple 23 mm anti-aircraft cannon and usually fires short bursts of 3-4 seconds delivering approx. 200 rounds per burst.
The following examples of models which are still in use give estimated average values while various modifications can have enhanced performances:[102]

Category	Type	origin	weight	canons, MG	ATGW	crew
AIFV	BMP-1	USSR	13,000 kg	73mm gun	AT-3 Sagger	3 + 8
AIFV	BMP-2	USSR	15,000 kg	30mm cannon	AT-5 Spandrel	3 + 7
AIFV	BMP-3	USSR/Russia	18,700 kg	30mm can+100mm gun/AT-10		3 + 7
AIFV	M-2 Bradley	USA	32,660 kg	25mm can.+7,62	TOW	3 + 6
AIFV	Marder 1A3	Germany	38,500 kg	20mm can.+7,62	Milan	3 + 6
AIFV	Marder 2	Germany	43,000 kg	35/50mm can.+7,62	PARS-3MR	3 + 6
AIFV	Puma	Germany	up to 43,000 kg	30mm can. + 5,56 76mm Grenade Launcher	Spike LR	3 + 6
AIFV (or AT)	AMX-10P	France	14,200 kg	20mm can.+7,62 or	HOT	3 + 8
AIFV	VBCI	France	25,600 kg	25mm can.+7,62		2 + 9
AIFV	MCV-80	UK	24,000 kg	30mm+7,62		2 + 8
AIFV	FV510 Warrior	UK	24,500 kg	30mm+ 2x7,62		3 + 7
AIFV	ASCOD/Ulan	Austria/Spain	28,000 kg	30 mm can. + 7,62		3 + 8
APC	Stryker ICV	USA	~20,000 kg	40mm grenade launcher/12.7 MG		3 + 9
APC	BTR-90	USSR/Russia	21,000 kg	30mm can.+40mmAGL+AT-5		3 + 7
APC	Boxer	Germany	~35,000 kg	12,7/7,62mm or 40mm AGL		3 + 8
SHORAD SP	ZSU-23-4	USSR	14-20,000 kg	4 x 23mm (57round/s, 2,000m range)		4

Newer models combine AIFV-features with the armaments of a light tank such as the Russian BMP-3 that can deliver HE-shells and AT-10 missiles from a 100 mm direct fire canon at ranges up to 4,000 m (shell) and 5,000 m (ATGW).

In contemporary wars, particularly in the Middle East, light machine canons mounted on light trucks and pick-ups are widely used by irregular forces. Given the instability of such light wheeled vehicles with soft suspension the precision of fire bursts is significantly degraded causing wide scattering of impact far outside the intended target area.

d. Anti-tank Guided Weapon Systems (ATGW)

Anti-tank guided weapon systems (ATGW) fire guided missiles from light launchers which are either man-portable or mounted on armoured combat vehicles or trucks. They engage predominantly tanks, armoured vehicles and field fortifications with high explosive hollow-charge warheads at effective ranges between 2,000 and 5,000 m. ATGW are typically assigned to light infantry units which do not dispose at battle tanks and heavy armour.

[102] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 161, 171-176; http://www.army-guide.com/ eng/product.php?prodID=1023&printmode=1; http://www.tanks-encyclopedia.com/coldwar/USSR/BMP-2.php http://www.tanks-encyclopedia.com/coldwar/soviet/bmp-3.php https://de.wikipedia.org/wiki/Stryker_Armored_Vehicle; http://military-today.com/apc/marder_2.htm; https://en.wikipedia.org/wiki/Puma_(IFV); https://de.wikipedia.org/wiki/ASCOD https://de.wikipedia.org/wiki/AMX-10P; https://de.wikipedia.org/wiki/ M2/M3_Bradley ;

Most ATGW are wire-guided anti-tank weapons with a semi-automatic line-of-sight command. Missiles contain a rocket motor, a wire-guided flight control element and a shaped charge HE warhead. They are operated from a firing-post comprising a tube, an optical sight, an infra-red or other sensor tracker and, if dismounted, a tripod mount for infantry.

Missiles are ejected by a thin first boost charge from the launch tube with the propellant pressure and gases either evading through the rear tube-nozzle with little recoil or discharging the tube backwards (Milan). At safe distance, the sustainer burn of the rocket motor is ignited which propels the missile close to a line of sight trajectory towards the aim point. Such two-stage launch causes initial slow speed (approx. 75 m/sec for Milan) and a short downwards slope of the missile after launch before the rocket motor accelerates the missile to maximum speed (approx. 200m/sec for Milan) and, together with unfolding wings, stabilizes the flight path. Jet-spoilers in the sustainer motor rocket exhaust enable fine flightpath corrections until the time of burn-out. Speed, burn-out time and effective ranges vary according to different types and models and can cover maximum distances of 2,000 - 5,000 m.

During the flight of the missile, the operator has to match steadily the target with the optical cross-hairs while a computer compares aim point and flight path and translates necessary corrections into steering commands which are transmitted by wire to the jet-spoilers of the rocket motor. Such technology enables a very high hit probability under ideal battlefield conditions provided the crew is well trained and remains undisturbed during the command process. Terminal-phase guidance by use of infra-red or other seekers can further enhance the hit probability. Furthermore, night firing capability is provided by additional night sight devices such as the thermal imaging device MIRA for Milan.[103]

However, as the flight time lasts between 8 and 20+ seconds, the operator needs a clear sight to the target throughout the flight of the missile. If a mobile target disappears behind a natural elevation or artificial structure, if bushes, trees, buildings and electric power lines interfere with the wire, if smoke screens and battlefield fog blur the sight or the operator comes under enemy fire, semi-automatic command line-of-sight (SACLOS) ATGW can fail and the missile will land and detonate at random after burn-out.

Therefore, a new generation of “fire-and-forget” weapons were developed that are in a position to track and pursue the target without further control by the operator once the missile is locked on the target. Overflight top attack capability and terminal-phase homing through infrared, optical laser or magnetic sensor guidance increase hit and penetration probability. Most missiles remain wire-guided though since a complete sensor guidance would render them vulnerable to jamming. Thus, SACLOS ATGW still belong to the standard armaments of armies worldwide and are also widely used by regular and irregular forces in contemporary wars. ATGW (e.g., Milan, TOW) have been delivered by the United States, Turkey, France, Germany and others to militias and non-state actors in Iraq and Syria.

HE shaped charge warheads of missiles weigh between 2.4 and 6 kg containing approx. 60 % explosives. Their performance against armour and concrete is similar to HEAT warheads of projectiles fired by guns. Lethal effects can cover distances of 20-30 m from the detonation point (e.g., HOT 2MP). Improved versions with longer extensible probes and delaying resonators as well as tandem warheads have been developed to achieve stand-off distance for higher ERA armour penetration. Enlarged and heavier missiles can also cover increased ranges.

[103] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 163

Type[104]	Launcher Weight	Missile weight	Warhead / Weight	max. Speed	max. Range	seconds to target
I-TOW	106 kg	19 kg	shaped charge/3.9 kg		3,000+ m	21
TOW-2	106 kg	22 kg	shaped charge/6.1 kg	280 m/sec	3,750 m	15
HOT-3		24.5 kg	shaped charge/6,5 kg	240 m/sec	4,300 m	18
Swingfire		27 kg	shaped charge/7.0 kg	185 m/sec	4,000 m	23
Milan	16.4 kg	6.7 kg	shaped charge/2,7 kg	200 m/sec	2,000 m	10-12
Milan3/ADT/ER	28 kg	11.8 kg	shaped charge/>3 kg		3,000 m	~15-18
AT-3 Sagger	25+ kg	10.9 kg	shaped charge/2.6 kg	100 m/sec	2,500+ m	~25
AT-4 Spigot	23+ kg	11.3+ kg	shaped charge/1.8+ kg	~200 m/sec	2,500 m	~12
AT-5 Spandrel	25+kg	14,6+ kg	shaped charge/2.76 kg	~200 m/sec	4,000 m	~22
AT-6 Spiral	35+ kg	21+ kg	shaped charge/5.4 kg	~250+ m/sec	5,000 m	~22

2.4.2 Targeting of unguided munitions of DFWS

As DFWS are directly targeting at line of sight, all targeting processes are carried out by the crew operating the weapon system. That means gunners lay the barrels on the target with minimal traverse deviations if the gun is properly adjusted by test firing. Given the bent trajectories of projectiles precise ranging and adequate gun elevation are crucial. In earlier tank models the gunner used an optical sight and lined it up with the target while stadiametric or coincidence type optical rangefinders assisted in determining the target range. Also coaxial machine guns were used to test the accuracy of impact onto the target.

The introduction of laser rangefinders and of ballistic computers brought a significant enhancement of accuracy and speed of targeting. Thus, modern rangefinders can determine a range of 2,000 - 3,000 m with an accuracy of +/- 5 meters.[105] Modern fire-control systems are able to adjust the barrel by processing a number of additional factors such as the type of munition, wind speed and direction, air temperature and humidity, the wear and temperature inside the barrel and the angle of the target relative to the firing position, even when the tank is in motion. Full two-level gun stabilization allows modern tanks to fire while moving. A modern tank such as the Leopard 2 with a 120 mm Rheinmetall L55 gun can achieve a precision of several rounds (APFSDS DM 53) landing within an area measuring 9 cm high and 34 cm wide at a distance of 2,000 m provided that the crew is well trained.[106] Moreover, the gun is fully stabilized, enabling it to be laid and fired on the move with a high first shot hit probability.

Also night fighting capabilities have been improved significantly by the introduction of infra-red searchlights and further enhanced passive night-vision equipment that cannot be detected by infra-red scanners.

It should be noted, however, that most regular and irregular forces in the Middle East hold elder tanks, munitions and targeting equipment in their inventories which have significantly less precision and accuracy. Lack of training, shortcomings in maintenance of available systems and the

[104] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 162, 163, 165; D. Miller, et al., East v. West. The Balance of Military Power. Loc. cit., p. 100, 101, 103; http://www.military-today.com/missiles/milan.htm; http://www.deutschesheer.de/portal/a/heer/start/technik/handwaffen/milan/!ut/p/z1/04_Sj9CPkssy http://www.armed forces.co.uk/Europeandefence/edequipment/edmis/edmis6a9.htm; http://www.military-today.com/missiles/swingfire.htm; http://army-guide.com/eng/product2104.html

[105] C. Campbell (Ed.), Understanding Military Technology. Loc. cit., p. 99

[106] S. Paunila (GICHD), N.R. Jenzen-Jones (ARES) (Ed.): Explosive Weapon Effects. Loc. cit., p. 35, referring to data provided by Rheinmetall

application of Cold War massive area fire doctrines aggravate such problems. Given the high explosive power of warheads, misses can result in in unintended collateral damage at far ranges.

2.5 Air-launched munitions

2.5.1 Delivery means, munitions, effects

Air power enables strategic and operational command levels to choose or change the centre of gravity in theatres of war rapidly by combining long-range, high speed and significant firepower. Thus, air attacks always entail an element of surprise. Air-launched munitions are delivered by combat aircraft, combat helicopters and remotely-piloted unmanned combat aerial vehicles (UCAV, “armed drones”) for various purposes:

- Fast flying combat aircraft are the most flexible air delivery systems as they can reach far distant targets in short time with a flexible weapons mix including guided and unguided bombs, unguided air-to-ground rockets, guided air-to-ground and air-to-air missiles as well as machine canons pending the category and type of aircraft and munitions. Thus, they are best suited for counter-air missions to destroy the enemy’s defensive and offensive air power, strikes in the depth of the enemy’s operational and strategic dispositions and close air support for friendly ground forces in the centres of gravity of the land battle.

- The comparatively slow flying anti-tank attack helicopters (ATH) and multi-purpose combat helicopters (MCH) cover significantly lower ranges than combat aircraft but are in a position to exploit very low flight levels using terrain features for protection against early detection. They are equipped with rockets, missiles, bombs and canons released or fired at visual range and thus well suited for close air support of own troops and the combat against opposing armoured units. Therefore, ATH and MCH are often used for reinforcing ground capabilities in tactical centres of gravity.

- Unmanned remotely-piloted armed drones (UCAV) usually fly slower and carry less weight than fighter bombers but use the same array of sensors. They have the advantages of extended endurance in selected target areas and immediate reactivity. I.e., their loitering capabilities combined with precise and effective armaments – in current versions mainly precision-guided air-to-ground missiles – enable them to survey distant terrain continuously for a longer time span than a fighter bomber which has only limited time over the target area. Thus, a UCAV can detect and locate targets that appear only rarely and for a short while within a longer time of observation. The piloting crew can then react immediately and fire a missile once the target has been identified and confirmed. At the same time, the target area continues to be under observation so that the attack process can be delayed or interrupted if the targeting conditions on the ground change.

The nature of the air war changes with the nature of the conflict. In an asymmetric war absolute air supremacy can be used to harass and destroy the opponent on the ground as he does not possess any effective air defence, maybe with the exception of man portable, shoulder-fired ground-to-air missiles, light canons or ATGW on pick-ups which have limited short-distance anti-air effect only. However, in a high intensity conflict where both opponents deploy modern, highly effective and long-range air attack and air defence capabilities, principally two options can be pursued to retain penetration capabilities of own combat aircraft:

- *First*, enhancement of penetration potentials such as Stealth characteristics to evade radar detection or passive protection against approaching missiles (feint diversion and electronic counter measures) or suppression of enemy air defence (SEAD) operations through electronic jamming, suppressing and destroying ground-to-air missile sites;

- *Second*, enhancement of stand-off capabilities of munitions delivered by combat aircraft through increasing ranges and precision of munitions. Thus, stand-off munitions, i.e. long-range air-to-surface missiles can be delivered far outside the area protected by capable air defence missiles. In that case, the aircraft only transports the munition to a point of delivery far away from the battlefield while the stand-off air-to-ground missile reaches the target after autonomous flight with some variants allowing for remote-control.

For all such air-to-ground attack missions, different munitions have been developed to engage ground targets such as guided and unguided free-fall bombs, short-range unguided air-to-ground rockets and short-, medium- or long-range guided air-to-ground missiles (ASM). In addition, anti-tank guided weapons (ATGW) are used by ATH and UCAV and machine canons by combat aircraft and combat helicopters. All such munitions contain warheads with high explosives of various types, often combined with fragments. Similar to artillery shells, detonations of air-delivered munitions cause blast, heat and fragmentation. Size and mixture of explosives depend on the military purpose to be achieved. Special armour-piercing munitions are used to destroy armoured vehicles and penetrate reinforced concrete.

A traditional 500 lb unguided gravity bomb (approx. 230 kg weight) contains approx. 87-105 kg high explosives (38-45 %).[107] A classical Mk-82 500 lb aircraft bomb contains 89 kg of high explosive in a forged steel body weighing 142 kg. Its detonation would produce a crater with a diameter of 5 to 11m and a depth of 0.8 to 4.3m, pending the angle of impact and the type of ground. It causes the designed fragments of less than 20 grams each, together with natural fragments, to travel at 2,400 m/sec and penetrate 32 mm of steel armour plate at 16 m from the point of impact and 200 mm of concrete even beyond that distance. It would produce a lethal area around the point of detonation with a radius of 31 m in which most people would be killed, most buildings collapse and heavily built concrete structures be severely damaged. Still at a radius of 250 m 10 % of unprotected people would likely to be incapacitated. Only at a distance of 425 m would the probability of incapacitation shrink to 0.1 %.[108] For a Mk-83 1,000 lb (~455 kg) bomb such safety distance would increase to 475 m, for a Mk-84 2,000 lb (~910 kg) bomb to 500 m.[109]

The detonation of a Mk-84 2,000 lb bomb produces a crater of approx. 14 m width at the point of impact. "*At around 30 m from the point of detonation … most people would be killed (by blast) and even reinforced concrete buildings can be expected to be demolished*."[110] Even beyond the 30 m distance from the point of impact residential buildings are likely to collapse. Lethal fragments would be dispersed within a radius of approx. 365 m with some fragments flying as far as 1,150 m.[111]

In contrast, for precision-guided munitions (PGM) like the AGM-65 Maverick missile which deploys a smaller yield of 60-130 kg only, the safety radius can be diminished to 100 m.[112] Special

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[107] Loc. cit., p. 82, 83
[108] Loc. cit., p. 48, 84; cf. PAX / Article 36: Areas of harm. Loc. cit., p. 43
[109] PAX / Article 36: Areas of harm. Loc. cit., p. 43
[110] PAX / Article 36: Areas of harm. Loc. cit., p. 11, 38
[111] Ibid.
[112] Loc. cit., p. 43

"bolt-on" guidance packages such as the Joint Direct Attack Munition (JDAM) have been introduced to convert unguided gravity bombs into precision-guided munitions.[113] While such conversions reduce CEPs significantly it is important to note, however, that the immediate area effects of explosions around the point of impact are not reduced but depend on the size of the yield.

The following examples of stand-off air-to-surface missiles (ASM) and laser-guided bombs indicate ranges and sizes of warheads:

ASM[114]	origin	Launch weight	warhead	max. range	max. speed	launch-to-target
AS-4	USSR	5,900 kg	1,000 kg	460 km	Mach 3.	7 - 12 min
AS-5	USSR	3,000 kg	1,000 kg	230 km	Mach 1.2	10 - 14 min
AS-7	USSR	1,200 kg	100 kg	11 km	Mach 1	30 - 40 sec
Kh-25	USSR	~300 kg	90-140 kg	11-60 km	Mach 0.9-2.0	36 - 90 sec
Kh-65SE	Russia	1,250 kg	410 kg	300 km	Mach 0,75	~20 min
3M-54Klub	Russia	1,300-2,300kg	~500 kg	220-2,500km	Mach 0.8-2.9	~13 - 42 min
AGM-109HKL	USA	1,000-1,200kg	295-450 kg	2,500 km	Mach 0,7	~175 min
AGM-86C/D	USA	1,430+ kg	900-1,360 kg	1,100+ km	Mach 0.73	>70 min
JASSM-ER	USA	1,020 kg	450 kg	1,000+ km		
TAURUS	German-Swed.	1,400 kg	481 kg	500+ km	Mach 0,8-0,95	~25 min
Storm Shadow	UK/FRA/ITA	1,300 kg	450 kg	560+ km	Mach 0,8-0,95	~30 min
AGM-158	USA	1,020 kg	450 kg	370+ km	sub-sonic	~25 min
AGM-84H/K	USA	675 kg	221 kg	270 km	Mach 0.7	~20 min
AGM-88 HARM	USA	360 kg	66 kg	150 km	Mach 2+	3-4 min
Maverick A-G	USA	210-300 kg	57-136 kg	16-40 km	Mach 1,2	36-100 sec
Hellfire	USA	~47 kg	8-9 kg	7-9 km	Mach 1,3	~20 sec

Laser Guided Bombs[115]

GBU-15 USA 2,000 lbs (907 kg) 10-28 km sub-sonic 30-70 sec
GBU-10/12/16/58 Paveway II USA 2,000/500/1,000/250 lbs (907/227/454/113 kg)
GBU-48/49/50/59 Paveway III USA 1,000/500/2,000/250 lbs (enhanced GPS & laser guidance)

Within a net-centric approach also sea-launched cruise missiles (SLCM) can complement air attacks against land targets. E.g., a SLCM Tomahawk (BGM-109A-E)[116] has a 1,900 kg launch weight and can hit targets with high precision at a range of up to 2,500 km (mod. A, C) with an average speed of 885 km/h. An air-launched version (AGM-129) exists with similar capabilities.[117]

2.5.2 Targeting

As precision-guided munitions are costly and even for advanced forces available in limited numbers only, still unguided rockets and free-fall gravity bombs account for the bulk of inventories of air forces globally. The accurate use of such munitions requires pilots to fly close to the target and

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[113] https://en.wikipedia.org/wiki/Jpoint_Direct_Attack_Munition

[114] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 117; http://www.military-today.com/missiles/hellfire.htm; https://en.wikipedia.org/wiki/AGM-86_ALCM; http://military.wikia.com/wiki/AGM-84H/K_SLAM-ER; https://en.wikipedia.org/wiki/KEPD_350; http://www.designation-systems.net/dusrm/m109.html https://fas.org/nuke/guide/russia/bomber/as-15.htm; https://en.wikipedia.org/wiki/3M-54Klub; https://en.wikipedia.org/wiki/Kh-25; http://designation-systems.net/dusrm/m-65.html

[115] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 121; http://www.raytheon.com/capabilities/products/paveway-laser-guided-bomb/; http://military.wikia.com/wiki/Paveway

[116] R. Bonds (Ed.): The Illustrated Directory of Modern Weapons. Loc. cit., p. 18; http://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=1300&ct=2

[117] http://military.wikia.com/wiki/AGM-129_ACM

release the weapon at visual range similarly to direct firing ground weapon systems. To that end, pilots use optical, infrared and thermal imaging sight equipment and carry out certain flight manoeuvres to deliver the munition at the right point, altitude and time. Therefore, accurate targeting requires intensive training.

Modern stand-off capability certainly changes the traditional line-of-sight targeting of combat aircraft towards an indirect targeting in which missiles, once released, can attack a predetermined target independently from further guidance by pilots. In these cases, the piloting crew has the task to select and fine-tune the munition on the target and release it at a point from which it can reach the target area. The aircraft is used for weapons transport and delivery, communication and data links rather than for combat. However, advanced versions of air-to-surface stand-off missiles (ASM) such as the AGM-84H/K SLAM-ER allow remote control while in flight and redirecting to another target after launch if the situation so requires.

An AGM-158 JASSM with ranges between 370 and 1,000 km is guided by inertial navigation with global positioning system (GPS) updates. Target recognition and terminal homing is based on an imaging infrared seeker. A data link allows the missile to transmit its location and status during flight which provides a basis for improved bomb damage assessment.[118]

An anti-tank guided missile AGM-114 Hellfire employs semi-active laser guidance. The missile homes-in on a laser spot produced by a laser designator. The target can be lased by the delivery aircraft, helicopter or UCAV, another aircraft or by a fighting vehicle or personnel with a man-portable designator on the ground. The flying delivery platform only points in the direction of the target when launching the missile and can then stand-off or remain terrain-masked while the missile follows the laser beam. Multiple simultaneous firing is possible. This guidance method ensures a very high hit probability within an extremely small CEP as long as the laser spot works without interruption. A newer version (AGM-114L) replaced the laser seeker head by a millimetric wave active radar homing. It homes-in on its target by image recognition like an electro-optical guided weapon.[119]

Such precision does not only increase strike precision but should also be used to to reduce unintended collateral damage. It should be stressed, however, that precision alone is insufficient if the yield of the munition has not been tailored to the target and the surrounding environment. Furthermore, accurate intelligence and target selection is a pivotal precondition to meet both military objectives and restrictions by international humanitarian law. Even highly precise delivery could fail to achieve the military purpose and produce devastating effects on civilians if based on false assessment of the nature of the target, its location and the situation of the civil population in the impact area. Sustainability of target surveillance[120] and reactivity of weapons delivery are crucial to avoid time delays that could lead to changes in the target area. That includes uninterrupted target identification and tracking (e.g. by UAVs and visual observation) and sustained guidance of delivery (e.g. laser designation) as well as the availability of weapon systems that can react immediately such as long-range artillery, combat aircraft when available, and UCAV loitering over the target area.

2.6. Preliminary conclusions

[118] https://en.wikipedia.org/wiki/AGM-158_JASSM

[119] http://www.military-today.com/missiles/hellfire.htm

[120] As to technical means of intelligence, surveillance and reconnaissance (ISR), target acquisition and tracking see section 2.3.2.c. of Chapter II.

(1) Most of the ground- and air-launched munitions in use by armed forces and irregular armed groups – except for kinetic energy canon rounds and small arms – carry high explosives to achieve military purposes such as penetrating and destroying armoured targets and hardened objects or covering wider areas where mass targets are dispersed or single targets cannot be located exactly. To that end, area effects are multiplied by repetitive firing of groups and salvos of shells and rockets.

(2) All detonations of explosive weapons cause blast, heat and high-speed dispersion of fragments within a circle around the point of impact. Such area effects occur irrespective of the question whether the projectile or warhead hits precisely the aim point. The lethal and incapacitating area around the point of impact depends mainly on the yield, the composition of high explosives and fragments, and the setting of fuses.

(3) Inherent imprecision of delivery systems, various types and production lots of munitions, charges and fusions, as well as environmental conditions influence trajectories of projectiles or rockets and times of detonation leading to variations in the points of impact. Such imprecisions are typical for indirect fire weapon systems and increase with range. They cause – often significant – deviations of the point of impact from the aim point resulting in enlarged lethal and incapacitating areas. However, area effects can be militarily intended. In particular, the release of MBLR salvos produces large-scale area effects.

(4) Inaccuracies of targeting processes, firing procedures and communication can multiply the technical imprecision of indirect fire delivery systems and munitions. Direct fire weapon systems can reach a much higher degree of precision.

(5) Professional armies enhance the reliability of weapon systems and munitions by extensive life-firing testing, assessment of data and translation into field manuals while the performance of crews is improved by intensive training.

(6) Advanced guided munitions can greatly enhance the precision of delivery and, thus, allow for smaller yields and reduced area effects when directed against single point targets. Modern target acquisition sensors and fire control systems improve the accuracy of delivery and the reaction time. In particular, sustained area surveillance can assure that the selection and delivery of munitions responds to the actual situation in the target area.

(7) Unclear and rapidly changing battlefield conditions with enemy counter-measures, quick target movements and fluid combat situations can result in insufficient intelligence and target reconnaissance, disruption of communications and delays of weapon delivery in the target area. That can lead to false situation assessments, failures of targeting and unintended collateral damage even if highly precise weapon systems are used.

(8) In contemporary non-international wars, regular and irregular ground forces use elder armaments and targeting equipment with low technical performance and professional skills due to the lack of training and adequate doctrines.

Part III

Military Operations in Populated Areas: Strategy, Tactics, Restrictions

3.1 Scenarios

During recent years, the use of explosive munitions in populated areas was observed in three different scenarios:

(1) Terrorist attacks in countries that were not affected by international or non-international armed conflict nor warlike conditions in context with internal turmoil; such terrorist attacks were countered by national law-enforcement action, in many cases in cooperation with intelligence and security agencies of other states.

(2) Surprise assaults and hit-and-run attacks by armed opposition or terrorist groups in low-intensity asymmetric war scenarios, often in context with the presence and stabilizing operations of multinational foreign forces based on a UNSC mandate; such attacks were countered by government and multinational coalition forces through limited military pin-point

operations as opposed to geographically extended, large-scale and intensive conventional battles. Cases in point are operations in Afghanistan and Mali.

(3) Full-fledged internal wars between government forces and armed opposition with both sides being supported by regular forces of foreign countries and militias raised in the affected country itself and abroad. While the ground warfare was characterized by the – largely symmetrical – use of elder types of weapons and munitions, only the use of air attacks on the government side and of highly sophisticated munitions by coalition air forces generated an element of asymmetry in warfare. This situation was and is typical for the multifaceted internal wars in Syria, Iraq and Yemen that have become an international character due to the active military intervention of foreign powers. In the case of Syria, various intervening powers support different factions through extended air campaigns, large-scale logistical supply, command, control, communications and intelligence as well as limited support on the ground, e.g. with special operation forces.

A fourth scenario was not observed, namely

(4) national or collective defence in a high-intensity symmetric conventional war against a full-scale military aggression in which both sides dispose at large ground, air and sea forces and highly advanced military capabilities.

The military significance of combat in populated areas and military necessities to use explosive weapons in urban terrain depend on such scenarios. Consequently, the question whether and to what extent combat in populated areas can be avoided and what could be done to reduce the effects of the use of explosive weapons on the civilian population cannot be answered by one set of generally applying responses without considering the differences in political purposes and subsequent military strategies prevailing in each scenario. A full-fledged defence scenario in which large-scale, geographically extended operations dominate the battlefield and vital national interests are at stake require different rules of engagement (ROEs) compared to stabilizing operations in a low-intensity, asymmetrical scenario in which tight ROEs restrict the use of weapons and the geographical choice of battle spaces.

3.2 Strategy

Populated areas, in particular major cities, are not only accumulations of civil populations but also centres of national power resources such as political administration, information, communications and transport, financial management, technological development, industrial production, commercial trade, energy and food supply, etc. Apart from their political, economic and symbolic significance they are also highly relevant in military terms as they generate personnel, production and logistical supply while the density of structures and buildings slow down fast mobile operations, complicate situation assessment and target acquisition. They present obstacles for visual range and precisely targeted weapon effects, thus reducing directly aimed fire ranges and providing for a certain degree of protection for defending forces which multiplies the means needed for offensive operations.

Against this backdrop, and taking into account their high politico-symbolic importance, opposing parties to internal conflicts seek to either hold or take major population centres as the cases of Aleppo, Damascus, Mosul or Er-Raqqa demonstrate.

Also in case of a large-scale intensive conventional war scenario in Europe, operations guided by political decisions will aim at defending populated areas. However, rather than seeking battles within cities, mobile operations will try to thwart enemy advances before and in between major population centres in order to prevent fast enemy attacks deep into rear areas as such operations may lead to encirclements of cities and to the collapse of the national defence. At the same time, the defender will not wait until second echelons and reserves of the aggressor arrive at the battlefield but engage him in his own rear areas by far-range ground-, air- and sea-delivered weapons. In such attacks the use of explosive weapons is unavoidable as weapons effects are largely relying on explosive power.

Furthermore, even if such operations try to spare bigger cities, combat in populated areas would be unavoidable given the densely populated landscape particularly in Central and Western Europe. As an aggressor might use populated areas for deploying far-range tube and rocket artillery or ballistic missile launchers appropriate counter-operations must be designed.

In the framework of NATO’s forward defence strategies during the Cold War in which Germany would have become the central battlefield, German planners intended to spare major cities from intensive battles. Therefore, indirect defence through mobile operations around such centres were planned. However, given the dense population of Germany even in border areas, planners were quite aware that combat in populated areas was not entirely avoidable. Therefore, plans were made to evacuate large parts of the population from such areas in case of war. To what extend such plans could have been implemented, however, depended on the warning time available and on the success of initial defence operations close to border lines.
Given such risks which threatened the very national survival three conclusions were taken:

(1) Geostrategic, economic and demographic conditions in Germany would not allow to entirely avoid combat in populated areas without giving up vital national interest.
(2) Precautionary measures would not be sufficient to prevent high scores of civilian casualties if Germany were to become a battlefield.
(3) In order to evade the dilemma of choosing between civilian casualties and national collapse a strategy was developed that ensured both deterrence through integration in a defence alliance securing military balances and a détente policy that aimed at preventing war through mutual restrictions of military capabilities stabilized by arms control.

This example shows that protecting civilian populations from the effects of war requires more than prohibitions of weapons or restrictions of operations the intensity of which depends on military necessities derived from political purposes and geostrategic conditions. Thus, assessing military necessities in proportion to expected (though not intended) collateral damage remains dependent on scenarios and national defence requirements. In an all-out defence scenario mass targeting is unavoidable while frictions in operations – such as lacking intelligence, enemy counter-measures, technical and personnel failures, unexpected obstacles to carry out effective warning, evacuations and protection of civilians – are the normal rather than exceptions.

Against this backdrop, any believe in the technical feasibility of fighting a “clean war” remains an illusion. Therefore, the only truly effective means to protect civilian populations from the effects of warfare is preventing war – fortified by negotiated reconciliation of strategic interest and arms control agreements. Arms control agreements, however, mean restricting overall military options rather than prohibiting or curtailing single weapon effects or combat operations.

Such considerations should also be taken into account when states decide to deliver armaments or provide logistical support to countries or armed factions involved in internal wars or military interventions. As long as parties to a conflict can rely on such support they will have an incentive to carry on combat operations with the ultimate objective to gain political victory on the battlefield, regrettably, in most cases without consideration of human losses. In consequence, such prolongation of internal wars with deteriorating military organizations, professional skills and moral standards will exacerbate the suffering of the civilian population.

3.3 Operations and Tactics

In asymmetric wars, groups of terrorists or insurgents carry out surprise attacks against selected targets in a largely empty battlefield which otherwise is characterized by a seemingly peaceful civilian environment. Government security forces, foreign troops entrusted with stabilization operations, cooperating countrymen and ethnic or religious minorities accused of betrayal are the predominant targets while IED attacks are the preferred means. Short-lived local control by insurgents of “liberated zones” in remote areas could belong to their desired military objectives. The political aim is to intimidate opponents, undermine the trust of the population in the ability of governments and foreign forces to guarantee for political stability and the protection of civilians and, thus, destabilize the political situation.

In such counter-insurgency scenarios, precisely targeted pin-point operations against single high value targets while protecting civilian communities and avoiding civilian casualties should be the predominant considerations when designing appropriate tactics. The use of precise weaponry with tailored effects after careful intelligence, sustainable surveillance, quick reaction after target acquisition, and comprehensive precautions are needed to destroy volatile targets while protecting civilians and preventing unintended collateral damage. Against this backdrop, a combination of a variety of intelligence and battlefield reconnaissance means, special operation forces, combat drones with enduring loitering capabilities and aircraft with precise munitions seem to be the means best suited to carry out counter-insurgency missions while, in certain hot spots, short combat operations of ground forces against insurgents or terrorists might also be necessary.

However, the deployment of precise weaponry against pinpoint targets in counter-insurgency scenarios which aim at avoiding civilian casualties should not lead to wrong conclusions as to the feasibility of such tactics being translated in full-scale symmetric war operations in order to conduct a “clean war”.

High intensity conventional warfare between equally capable opponents disposing at masses of forces and advanced weaponry differs fundamentally from the above small-scale asymmetric scenarios and requires different operations and tactics. In such scenarios, it is not the single weapon system or terrorist group which dominates planning but the entirety of forces and military capabilities, such as firepower, movements, command, control and communications, intelligence and logistics, which are deployed in large areas and carry out powerful air-land offensive operations at the frontline and in the depth simultaneously.

Against this backdrop, conventional warfare is not a duel between single weapon systems but a fight between opposing military systems that seek to accomplish operational missions with all assigned means in large areas by exploiting the synergetic effects of combined arms warfare. Commanders at the operative level determine where to take risks by deploying limited assets to only survey and lightly guard terrain, and where to seek a decision on the battlefield by massing forces, firepower and mobility. In particular, at these centres of gravity, troops face large numbers of targets simultaneously which renders massive area fire unavoidable.

Since attacks are carried out simultaneously against command and control, communication and intelligence, air and land combat power, transport and logistics, etc. the situation will often be unclear, full of uncertainties and unforeseen developments such as high losses of own troops and surprises as to enemy action. Despite such largely unpredictable operational environment, commanders have to engage in sober battlefield assessments, take decisions and gain the initiative in order to fulfil their mission and enforce operational and tactical objectives. Thus fire will often have to be directed at areas rather than at single precisely detected pinpoint targets. In consequence, considerations of particular effects of single weapon systems will be dominated by the assessment of synergetic effects of combined arms operations to achieve the military purpose.

The deployment of artillery in such combat situations presents an illustrative example: it does not only aim at destructions and attrition of enemy hardware but also at blinding enemy observation and suppressing direct fire and indirect fire support in order to enable own movements; and at disrupting command and control, communications and logistical transport or denying enemy advances across rivers and through other choke points. In other words, counting enemy personnel casualties due to direct hits is insufficient for evaluating military necessities and synergetic effects of artillery in combat as it does not consider intended tactical effects of combined arms operations.

However, also in such environment accuracy of target acquisition, reactivity of delivery means and precision of munitions are invaluable assets to secure superiority in battle. Time is a crucial factor since mobile operations change potential target positions quickly, and detected targets might have moved before strikes on target areas have been carried out. Therefore, reducing the time span between target detection and weapons delivery is paramount. Long-range artillery, combat aircraft and UCAV as well as the use of PGM and stand-off munitions are most suited to bridge that gap.

3.4 Restrictions: International Humanitarian Law and Rules of Engagement (ROE)

The basic requirements of International Humanitarian Law in regard of the protection of civilians have to be complied with in all scenarios and types of operations:

(1) Distinction between legitimate military targets and civilians or civilian objects
(2) Proportionality of attacks, i.e. military operations including the use of weapon systems
(3) Precautionary measures to protect the civilian population from the effects of warfare.

The principle of the proportionality of the use of weapons, munitions and operations takes into consideration both the need to achieve an imperative military purpose and the requirement to limit the effects of warfare to protect civilians. The exact implication of those requirements depends on the scenario. I.e., weighing the political and military significance of a certain military action in relation to the expected damage caused by such action might bring about different results in different scenarios.

In any case, the commander has to assess the military consequences and the collateral damage implications of using particular operations and weapon systems to achieve the military purposes. To that end, he will have to choose between various options (if available) including the options to use alternative methods, delay the action or not act at all. For the outcome he will have to bear responsibility.

In an asymmetric low-intensity scenario stabilizing military operations are geared to protect state functions, civilian populations, economic recovery and lines of communications rather than fighting field battles against powerful opposing armies. However, in some instances forces have to counter hit-and-run tactics of insurgent groups and protect themselves while on patrol. It is self-evident that under such conditions that require occasional pin-point operations proportionality calculations are quite different from high intensity conventional war scenarios. Every single use of weapons would be subject to very strict limitations in order to avoid non-intended collateral damage.

However, even in law intensity scenarios the complete renunciation of the use of explosive weapons in populated areas is no option as it would give opponents significant military advantages and higher certainty of success while own troops would be exposed to direct and indirect enemy fire and probably suffer high losses. An infantry platoon ambushed on patrol must be in a position to suppress enemy fire delivered at far ranges or from protected positions behind natural elevations or buildings. To that end, it needs indirect fire support.

To assure the protection of civilians against the effects of explosive munitions a variety of measures can and must be taken as the following examples demonstrate:

(1) Thorough intelligence, target reconnaissance, target acquisition and continuous surveillance of the target area until weapon delivery and beyond;
(2) Collateral Damage Estimate (CDE) for every option of a potential use of explosive weapons;
(3) Subsequent choice of appropriate weapon systems, munitions and fuses with high precision to avoid misses and low yields to curtail direct area effects, taking into account the size and category of military targets and the situation of the civil population;
(4) Where necessary, ensuring that laser illumination and other precision guiding methods function uninterrupted during the whole targeting process;
(5) To that end, keeping safety distances for friendly troops and civilians;
(6) Appropriate warning of the civilian population;
(7) Delaying or cancelling operations if civilians move too close to the target area and the military purpose can be achieved by alternative operations – however, with the exception of self-defence.

Such precautionary measures ensuring proportionality of military operations and a maximum degree of protection of civilians have become standard in a number of military operations in Afghanistan, Somalia and elsewhere and are enshrined in the Rules of Engagement (ROE).[121]

As indicated above, however, the reality of a high intensity conventional war might be different. The battlefield is characterized by quick mobile operations, the military necessity to fight mass targets simultaneously and deny areas to enemy advances rather than destroy pinpoint targets. In such circumstances, commanders have to act in unclear situations in which assessments are based on the will to take tactical risks in order to gain the initiative rather than on clear and comprehensive situation reports. Frictions in war are the rule, no exceptions. When taking decisions to strike, the situation in the target area might have changed if an earlier target acquisition has lost relevance and intelligence has failed to provide exact information in time. Command and control might be disrupted and thus fail to command delivery means and guide munitions on time.

Although proportionality rules apply at all times, their interpretation in a national defence scenario might differ from the above low-intensity scenario: Achieving the military purpose in national defence will become a dominating consideration while the complex, fluid and unclear situation diminishes the ability to achieve precision.
Nevertheless, the right of parties to the conflict to choose methods or means of warfare is not unlimited.[122]

[121] Such rules were implemented during ISAF operations in Afghanistan and KFOR deployment in Kosovo. Interview of the author with Lieutenant General (ret) Rainer Glatz, former commander of the Bundeswehr Joint Forces Operations Command, on 5 October 2017; see also PAX / Article 36: Areas of harm. Loc. cit., p. 34, 35

Furthermore, Additional Protocol I to the Geneva Conventions, Art. 36, requires states to determine whether the employment of a new weapon, means or method of warfare would, in some or all circumstances, be prohibited. That includes the obligation to design new systems accordingly, test them thoroughly, establish a reliable data base and translate the findings into field manuals and training instructions.

3.5 Armaments, doctrine, command and control, training

IHL rules require highest possible precision in targeting and restriction of disproportional or indiscriminate area effects of methods of warfare. However, the extent to which real military capabilities enable political and military leaders to comply with such rules do not only depend on their intentions and self-restriction but also on the availability of adequate reconnaissance and target acquisition, the technological standards of delivery systems and munitions, military doctrine, command and control systems and level of training.

In the countries observed, parties to the conflict mainly use armaments and munitions that were acquired between the 1960s and 1980s and have low technological standard. They are much less suited to carry out highly precise targeting and tailor weapons effects than modern precision guided munitions.

Furthermore, the ability to carry out organized combined arms operations depends essentially on the military doctrine of states or armed groups involved (if they have any), the effectiveness and resilience of their command and control system and the level of training for commanders and units. Many states in the region are still influenced by military doctrines which stem from Cold War times and prefer a rather static defence and massive area covering fire.

Syria is a case in point: a corps of professional units – the 4th Armoured Division, the 3rd Republican Guards Division and two Special Forces Divisions – with a collective strength of 25,000 represents the remaining offensive power while approx. 65,000 ill-trained personnel in scattered structures of the former Syrian Arab Army can only be used for static local defence. Iranian-led Shia militias from Iraq and Afghanistan as well as Hezbollah formations support the Syrian government whilst the armed opposition and terrorist organizations in Syria dispose at least of six larger formations with a collective strength of approx. 90,000 personnel.[123]

However, also their military performance is quite limited as was proven lastly during “Operation Euphrates Shield” of the Turkish army in North Syria carried out in cooperation with FSA units.[124] Generally, such units resort to repeated harassing fire or area shelling from static positions rather than focused mobile operations. Only the most powerful and experienced Islamist and Salafist groups such as the Al-Qaeda-linked terrorist organization Jabhat Fateh al-Sham (former al-Nusra Front/ANF), Ahrar al-Sham, Jaysh al-Islam and a number of units of the FSA Southern Front as well as the Kurdish-led Syrian Democratic Forces (SDF) have developed some professional skills to carry out combined arms operations.

[122] Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1997, Art. 35

[123] International Institute for Strategic Studies: *The Military Balance 2017*. London 2017, Chapter VII, p. 404-407

[124] Cf. Metin Gurcan: *Turkish Intervention: Ankara’s lessons from Euphrates Shield*. In: Jane’s, date posted: 09-June-2017, p. 5-8

These organizations have been supported by intervening powers, in particular, the United States, Turkey, Saudi Arabia and Qatar, that provided financial means, armaments, logistics, intelligence, command and control, and training from operation rooms in Turkey and Jordan. In consequence, these formations are particularly strong where they have direct territorial links to Turkey and Jordan while logistical support to enclaves in the centre of the country is limited as lines of communications are mainly controlled by government forces.

At the same time, Russia and Iran have supported the Syrian government either by direct military intervention or by raising and leading militias. Without such foreign aid and intervention the war between warrying factions in Syria could not have been sustained. Eventually, the Russian air campaign made the difference in 2016 and only in July 2017 the United States announced that it would stop arms deliveries to Syrian rebels that were carried out by the CIA since 2013 while the Pentagon will continue supporting the SDF in Northern Syria.[125]

Furthermore, years of a war that more and more is fought along ethnic, religious and ideological lines have produced existential fears, formerly unknown hatred and mistrust and, thus, deteriorated the moral standards of both sides neglecting the humanitarian consequences of indiscriminate and disproportionate warfare. Such observations are not irrelevant when assessing statistics about the effects of the use of explosive weapons in populated areas and calls upon western states to tighten their standards in combat.

3.6 Conclusions and recommendations

(1) The military necessity of using explosive weapons in populated areas depends on different needs in different scenarios. Consequently, the question to what extent it can be avoided and what could be done to reduce its effects on the civilian population cannot be answered by one set of generally applying responses.

(2) A full-fledged defence scenario in which large-scale, geographically extended operations with mass targets dominate the battlefield and vital national interests are at stake require different rules of engagement (ROEs) compared to stabilizing operations in a low-intensity, asymmetrical scenario. In such cases, civil protection and evacuation might be options to be considered.

(3) Also in a low-intensity scenario where troops have to carry out stabilizing operations a total renunciation of the use of explosive weapons is no option if enemy fighters should not be granted military advantages and own forces exposed to indirect and direct enemy fire. However, such use should be subject to tight restrictions as to the selection and use of delivery means and munitions and the geographical choice of battle spaces taking into account the situation of civilians.

(4) Any such use must be prepared by thorough intelligence, target reconnaissance, target acquisition and continuous surveillance of the target area up to the weapons’ delivery and beyond.

(5) Before the employment, a collateral damage estimate should be made for every option of a potential use of explosive weapons taking into account the situation of the civilian population.

[125] Cf. footnote 57

It should guide the subsequent choice of appropriate weapon systems, munitions and fuses and ensure high precision to avoid misses as well as low yields to curtail direct area effects.

(6) Continuous surveillance of the target area is necessary to enable last minute decisions and to ensure that laser illumination and other precision guiding methods function uninterrupted during the whole targeting and delivery process.

(7) Up to the end of the operation, safety distances for friendly troops should guide appropriate safety distances also for civilians. Commanders should issue an appropriate warning to the civilian population.

(8) The delivery should be delayed or cancelled if civilians move too close to the target area and the military purpose can be achieved by alternative operations. However, proportional self-defence of own troops must remain possible.

(9) Such rules should be enshrined in field manuals, rules of engagement (ROE), best practices and codes of conduct, and troops educated and trained accordingly.

(10) The interpretation of proportionality requirements in high intensity conventional war scenarios such as national defence might differ from the above low-intensity scenario rules, in particular in centres of gravity where achieving the military purpose becomes a dominating consideration while the complex, fluid and unclear situation diminishes the ability to achieve precision.

(11) States are required to determine whether the employment of a new weapon, means or method of warfare would, in some or all circumstances, be prohibited. That includes the obligation to design new systems accordingly, test them thoroughly, establish a reliable data base and translate the findings into field manuals and training instructions.

(12) Arms deliveries and logistical supply of regular and irregular forces in internal, non-international conflict prolong the war and the suffering of civilians, particularly, as deteriorating equipment, professional skills and moral standards lead to large-scale disproportional and indiscriminate warfare. States should therefore refrain from such support.

(13) In order to uphold the rule of International Humanitarian Law in war, the international community should record all incidents that could involve violations of such laws and the basic requirements of humanity, in particular, if such breaches are severe and repetitive and point at a general degradation of compliance and morale.

Despite the revolutionary development in precision and accuracy of delivery means and munitions, any believe in the possibility of conducting a “clean war” is flawed. In particular in high intensity scenarios, frictions at all levels and steps of target reconnaissance, target acquisition and location, targeting processes and weapon delivery will be the rule and no exception. War prevention is a more realistic concept. It includes confidence- and security-building measures and arms control that curtails military options and potentials for offensive operations.