Dan Kaszeta, Managing Director of Strongpoint Security, on trying to make the numbers balance…

Managing the deficit

The evidence seems clear that sarin (GB) was indeed used in Ghouta on August 21, but as an old Chemical Corps officer I can't make the numbers work and I've got a nagging suspicion that something strange is going on here. From the standpoint of a staff officer, I just don't think that there's enough shells and rockets to account for the number of victims. I can't make 12-14 rockets account for this much mayhem.

As an intellectual exercise let's pretend I was the Assad regime's chemical officer that night and do a "chemical target analysis", to reverse-engineer what a proper chemical strike would look like. Before the US renounced chemical warfare, chemical target analysis was part of the curriculum for a Chemical Corps officer and the subject of a special short course for selected artillery NCOs and officers. There's a whole lot more to chemical warfare than throwing some shells at the enemy and hoping to poison the other side's soldiers and contaminate their terrain and equipment. There is both science and art in it. During the Cold War, the US, Soviet Union and other countries with CW arsenals developed methodologies to assist their staff officers in planning chemical attacks. The US military's textbook for this was called Field Manual 3-10 "Employment of Chemical Agents", and at least the 1966 and 1971 revised versions are floating out there in the public domain for the enthusiast to find. Some of the grittier detail is in a classified sister publication, but the information in the 1966 version is good enough for what I need to demonstrate.

Two tools are of paramount use in this exercise. First is the "chemical ammunition expenditure tables". These tell the chemical staff officer, artillery crews, and logisticians how many artillery shells or rockets are likely to be needed for a particular exercise. Second is "chemical vulnerability analysis tables", many of which are still in current doctrinal publications. These tables help commanders and staff officers figure out their own vulnerability to strikes by opposing forces using chemical weapons. What the manuals don't tell you is that these tables are reverse-engineered from offensive target analysis data: one man's ammunition expenditure table is another man's defensive vulnerability analysis tool. By using these two tools, we can come up with a reasonable guess as to how much sarin is needed for an attack.

Unfortunately, we don't have all of the information to do this with a high degree of precision, due to the fog of war there's too much variance in the information available to me. To do our cocktail-napkin guesstimate here, we need casualty figures, weather data, and geography.

Let's start by examining the casualty figures. Depending on who you ask, there's anything from 200-ish fatalities to a remarkably precise 1,429 fatalities. Based on the reporting from various sources, there is a range from 6:1 to a 10:1 ratio of seriously affected victims to dead victims. This gives us a range of casualties of anywhere from 1,200 to 14,290.

Weather data is sparse, but two sources tell me that the winds on the evening of the attack were approximately 10 mph. This is good, neither too fast or too slow. The "air stability" – the chemical officer's indicator of vertical movement of air – is also critical to this equation. The fact that the strike occurred in the early hours of the morning suggests that the air stability was in the "inversion" category rather than "neutral" or "lapse": the best time of day to use a chemical warfare agent. Average low temperature in Damascus in August is 16.5°C and the record low as 13°C, according to World Meteorological Organization statistics, so we can safely assume that the temperature was well above freezing.

Finally, we need to identify the size of our target zone. A number of bloggers and journalists have been working on the size of the target zones and, while by no means authoritative, some interesting work has been done. Felim McMahon, a journalist at Storyful, has done splendid work in defining the size of the Zamalka/Tarma chemical strikes – this is the north-eastern-most of the two significant target zones (http://storyful.com/stories/63271). His analysis gives us a target zone of approximately 1,400 metres long and 450 metres wide, 630,000 square metres,

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i.e. 63 hectares: not a small target zone and several thousand victims in that zone is not a trivial casualty percentage. It is worth noting that a 630,000 square-metre zone is at the smallest end of the range of possibilities; earlier calculations were bigger.

If we use the tables for the US M121 155mm artillery shell, (which wasn't the weapon system used, but we can do conversion maths) the chemical ammunition table says inversion air stability plus above-freezing temperatures means I need two shells per hectare to get a 50% "coverage" of the target area with a casualty-producing dosage. This, however, is for an attack against troops in the open with little or no cover. If I am trying to attack troops in fortifications (buildings and cellars) or tanks, I need to plot to use six shells per hectare for a "total dosage attack" that relies on a smaller dose rate and time to allow for agent to build up or 24 shells per hectare for a surprise attack. The total dosage attack is not really for use against people who are going to run away, but rather to wear down those who stay and fight. As the chemical officer planning the attack, I'd say that the higher number (24 shells per hectare) is what's needed, as I would count the cellars and improvised bunkers that the population is hiding in as "fortifications" for the purposes of these tables. These charts and tables are the result of extensive testing both with simulated fillings and live agents at Dugway Proving Ground up until 1969.

These calculations give us a number of 155mm sarin shells required as somewhere in the range of 126 to 1,512 shells and the manual states that the M121 shell held 2.95 kg of sarin, so this nominal attack requires a best case of 372 kg up to 4460 kg of sarin. if the air stability was "neutral" instead of "inversion" we get somewhat higher numbers. 1,512 shells would make the chemical officer break his pencil and tell the artillery officer to just use conventional rounds! The US Army's conventional ammunition allocation for offensive operations ranges from 153 to 207 rounds per 155mm howitzer, based on operational tempo, which means that 1,512 shells is a good day's work for a lot of cannons.

Table 2-4. Sarin (GB) Casualties.

Munitions in Rounds per Hectare (10,000 m ^{2})			Temperature (degrees Celsius)			
MLRS	150-155 mm	120-122 mm	-12	0	10	20
			Casualty Percentage			
1	2	4	10	16	24	33
2	4	7	14	22	30	40
3	6	10	19	27	37	47
4	8	14	25	34	43	54
4	10	17	31	40	50	60

Based on 15 liter/minute breathing rate (rest or light work) and 15 second masking time.

★*Table VII. GB Ammunition Expenditures for the 155-mm Howitzer* [1]
(Projectile M121, PD fuse)

Temperature gradient	Wind speed (knots)	Rounds per hectare for 50-percent coverage [2] of a target area with a casualty-producing dosage [3] (Against troops in open or lightly wooded terrain) [4]					
		Surprise dosage attack [5]			Total dosage attack		
		0°-30°F	31°-60°F	Above 60°F	0°-30°F	31°-60°F	Above 60°F
Lapse	3	20	19	17	3	2.5	2.5
	5	11	9	7	5	4	3
	8	13	8	6	8	7	5
Neutral	3	10	9	9	1	1	1
	5	6	5	5	1	1	1
	8	6	5	3	2	1.5	1
	14	10	5	3	5	3	2
	28	22	10	5	11	7	5
Inversion	3	9	7	6	1	1	1
	5	5	4	4	1	1	1
	8	5	3	2	1	1	1

★[1] Weapon rate of fire (6 wpns/how btry): 1 rd/15 sec; 12 rds/3 min: 24 rds/15 min.
[2] For 30-percent coverage, multiply by 0.7. For 80-percent coverage, multiply by 1.6.
[3] See paragraph 67 for estimation of casualties.
[4] For jungle or heavily wooded terrain, use data for a 3-knot wind speed.
[5] TOT fire is recommended for maximum effectiveness; if not practicable see paragraph 58b.

Table XI. ★*GB Ammunition Expenditures for the 155-mm Howitzer Battery in the Attack of a One-Hectare or Smaller Target Containing Fortifications with Overhead Cover or Tanks*

Temperature gradient	Wind speed (knots)	Rounds per hectare for 50-percent coverage with a casualty-producing dosage				
		Surprise dosage attack [1]				Total dosage attack
		Dosage effects in 15 seconds		Dosage effects in 30 seconds		
		0–30°F [2]	Above 30°F	0–30°F [2]	Above 30°F	0–Above 30°F
Lapse	All [3]	N.S. [4]	36	N.S.	24	15
Neutral	Below 10	N.S.	36	N.S.	24	12
	Above 10	N.S.	36	N.S.	30	24
Inversion	All	N.S.	36	N.S.	24	6

[1] TOT fire is recommended for maximum effectiveness; if not practicable see paragraph 58b and e.
[2] Snow-covered terrain.
[3] Strong lapse or inversion temperature gradient can be expected only at low to moderate wind speeds, since high wind speeds eliminate stratification.
[4] Not suited. Munition requirements are unacceptably high, or agent cloud cannot be depended upon to develop significant casualties inside fortifications within this time interval.

Courtesy of Dan Kaszeta

When we use the "vulnerability analysis" tables, I get a situation that is broadly similar: Table 2-4 of *US Army Field Manual 3-14* gives very similar results. It states that I need two shells in the 155mm class to give a 33% casualty rate per hectare. I'm going to guess that a very similar algorithm was done to come up with this chart.

Numerous factors indicate that the actual figures are going to be towards the high side of our estimated range, if not exceed them altogether. I'd suggest that we can disregard the figures at the lowest end of the scale, 372 kg used against troops at their most vulnerable. While sarin is heavier than air, and will seek the low lying areas eventually, the urban environment will reduce the

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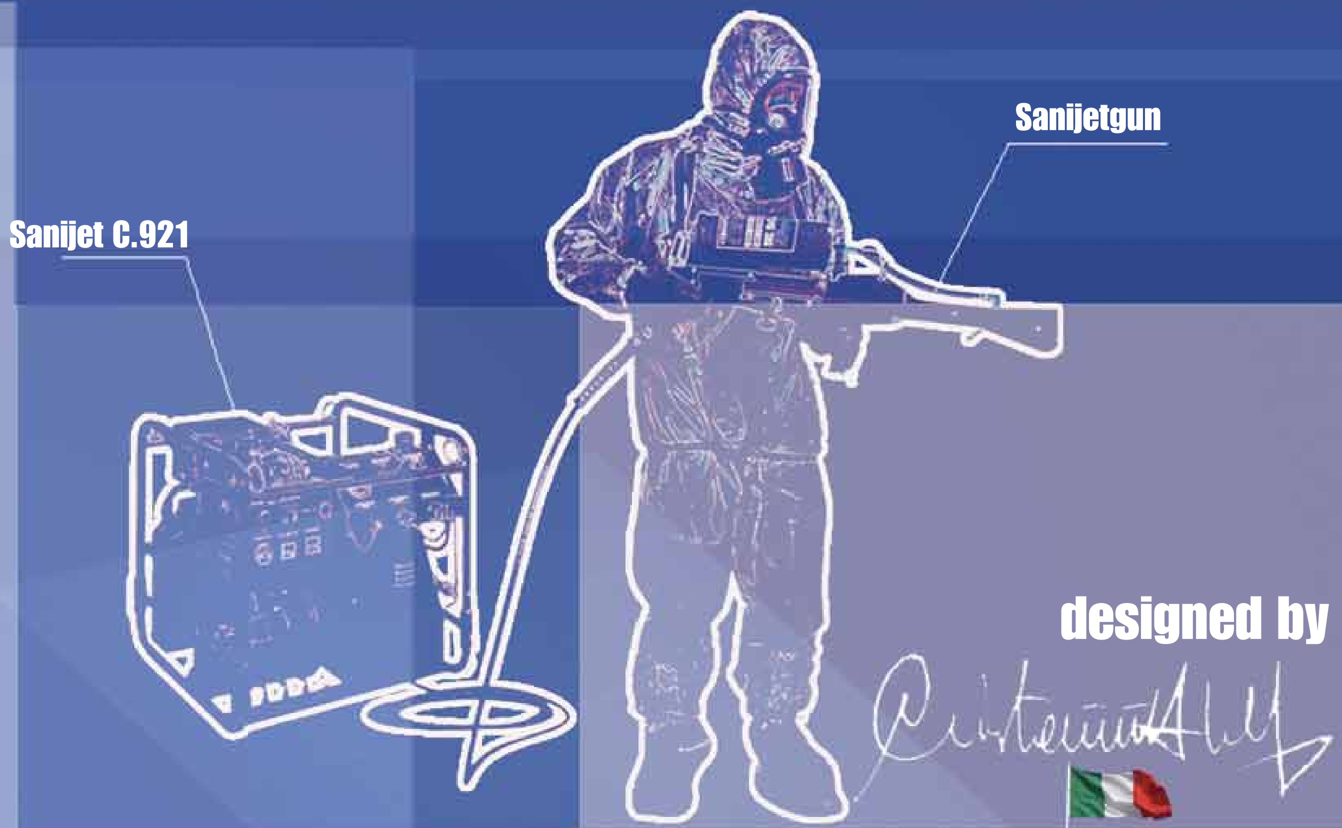

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efficiency of the chemical strike, as agent gets stuck on walls and ceilings, shells detonate on roof tops not at ground level, and even the leakiest building provides a limited protection factor against toxins in the air outside, even if only for a few minutes. A basic assumption behind the vulnerability analysis tables is based on a breathing rate of 15 litres per minute, but a sleeping person is likely to breathe at a slower rate, particularly children. This requires more agent for the same level of tactical effects.

Munition efficiency also needs to be examined. This is the percentage of the munitions chemical agent filling that is dispersed in the manner consistent with the desired effects. The munition efficiency of the weapon systems in the US target analysis tables are quite high, as they reflect lengthy testing, both with live agents and with simulants to optimise the design of the weapon and to discern the optimum bursting charge to chemical agent ratio. Say what you like, but the larger of the two rocket systems blamed for Ghouta just doesn't look like the product of a decade of R&D and numerous test firings at a proving ground! The smaller 140mm rocket may very well have US-style munition efficiency, but the larger 330mm system is unlikely to have the munition efficiency of the weapons used as a basis for the target analysis charts. Neither does it look like it had the proper chemical agent to bursting charge ratio (3.3:1 for the US M55 rocket), because if it did, there wouldn't be many pieces of it left to find.

Finally, there is agent purity, US sarin was the product of extensive R&D and was very pure. Impurities degrade the useful shelf life of the agent. Impurities in sarin, such as some noted by the UN's report, both point to a lower percentage of actual agent and a shorter life. All these factors lead to more agent being needed, not less.

This whole situation has given me notion that the real answer is somewhere near the 4400 kg of sarin end of the spectrum: the factors above are more likely to add to the required agent than subtract from it. 4,400 kg equates to 2,000 of the smaller 140mm rockets or, roughly 80 of the larger rockets. This confirms my suspicions, for a large target zone and a large number of casualties an attack requires a large amount of agent. US doctrine would have used air-delivered bombs for such a large attack as the only efficient means to deliver that quantity of agent, and even that would have been a very large strike. An interesting side to this discussion is the apparent fact that chemical weapons are often not very efficient at all, compared to their conventional counterparts.

So, what happened? Based on my understanding of chemical warfare, either a very large strike occurred or

Are we only seeing a small sample of the evidence? The defective rounds? ©E. Higgins

the perpetrators got extraordinarily lucky and managed to land, by pure luck, poorly guided munitions into close proximity of large pockets of victims. Luck, good or bad, happens on the battlefield and we can't exclude the possibility that a few rounds landed close enough to large aggregations of people. This would cause a lighter-weight attack to have an effect out of proportion to the old tables I used, which were based on statistical averages, not 95th percentile luck.

If a large strike happened, we are seeing only a small portion of the physical evidence. I think that the rockets we are looking at are defective or failed to function properly, as a properly sized bursting charge would shred such a thin-skinned rocket. The ones that detonated properly ended up as small fragments. I also strongly suspect that the large rocket was probably a poor attempt at a binary device, mixing several components to create sarin. The US military's experience with binary weapons shows us that perfecting an in-flight mixing system is actually very hard, and the 330mm Ghouta rocket seems unlikely to be a result of significant testing and development. A poorly executed binary weapon would disperse a cocktail of substances: a bit of sarin, a lot of precursors, and maybe some interesting by-products. All of the precursors and by-products would be general skin, eye, and respiratory irritants and toxic to an extent, possibly explaining the prevalence of generic signs and symptoms. At the end, I'm left with the idea that either we're missing at least 70 rockets or the attackers got awfully lucky on 8/21.