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Contemporary Tactical Military Use of Subterranea by Non-State Actors

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Abstract: *Contemporary military conflicts show that NATO needs once again to understand the significance of subterranea as an operational environment. Much previous subterranean knowledge, training and infrastructure was taken as a Cold War peace dividend and 'at risk' in subsequent defence reviews. Today, both state and non-state actors are utilising this space. NATO tactical-level subterranean experiences in Afghanistan have largely been with caves and tunnels in mountains*[2, 3]*. In contrast, conflicts in Syria and Iraq have centred on the need to hold or capture cities*[4]*. These conflicts have again shown how critical subterranean parts of cities are for the survival of both combatants and civilians. In rural settings, these same conflicts have seen combatants use natural subterranean features but also undertake significant military tunnelling and underground construction projects. The increased use of subterranea has been driven by the need to avoid detection and to*

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2 Such as Tora Bora, Shahi-Kot valley and Paktika.

3 Eugene Palka, "Military Operations in Caves: Observations from Afghanistan", in: *Military Geography and Geology: History and Technology*. (Paul Nathanail, Robert Abrahart & Roy Bradshaw (eds) Land Quality Press, Nottingham Chapter 19, 2008). p. 269-278.

4 Robert D. Barbaree, "Coordinating Chaos, Integrating Capabilities in Future Urban Combat". in: *Complex Terrain Megacities and the Changing Character of Urban Operations.* (Benjamin M. Jensen, Henrik Breitenbauch and Brandon Valeriano eds. Marine Corps University Press, Quantico, Virginia. Chapter 6, 2019). pp. 140-155.

increase protection in an attempt to reduce or overcome the technological advantages possessed by modern militaries, and to find advantage in their limitations. The scale of subterranean excavations was formerly to be expected by state actors but conflicts in Syria, Iraq, Lebanon and Gaza have revealed the significant capabilities and capacities of non-state actors. Examinations as to how rebel/terrorist groups have utilised subterranea highlights considerations for NATO forces response today and in the future. This is critical to understanding terrorist's intent and capabilities that are vital to identify measures, tactics, techniques or technology that can be introduced to counter the changing terrorist threat.

Keywords: *Subterranea, Survivability, Detectability, Vulnerability, Recoverability.*

1. Introduction

Non-state actors have demonstrated understanding of how modern militaries fight, how to reduce or overcome their technological advantages, and particularly how to exploit their limitations. Contemporary conflicts have revealed increasing levels of sophistication and capability in subterranean warfare in urban and rural settings. This requires changes in how modern militaries fight underground[5]. Subterranea encompasses both under land and seabed and is often not monitored by those who lay claim to the surface. It is a domain in which modern militaries cannot easily find an adversary, penetrate sufficient depths, fight in at-scale, for long duration, or manage captured underground tunnels and facilities[6]. This should engender debate as to the will and ability of NATO forces to be competitive in subterranean warfare at tactical, operation or strategic level, either by going underground, minimising direct engagement by destroying subterranean structures from above, or identifying and avoiding. To operate in this space the NATO land forces will need joint action with Air, Space and at times, Maritime forces. Subterranea is a domain also being exploited by organised crime and the same underground structures may be used for trade, smuggling (weapons, people, and drugs), movement of civilians and combatants. Depending on the circumstances, underground warfare

[5] Raphael Cohen et al., *From Cast Lead to Protective Edge.* (RAND Corporation, Santa Monica, California, 2017). p. 246.

[6] Mark Bulmer, Contemporary Military Use of Subterranea, (British Army Review, 175, 2018). pp. 106-113.

may fall within the scope of several domestic and international legal frameworks[7]. Both shallow (less than 20 meters below ground) and deep (greater than 20 meters below ground) subterranea, are complex operating environments[8] for defence and security agencies within the home countries of NATO members and overseas.

Several motives can be identified for the military use of subterranea in Iraq and Syria. First, since 2011, Syrian rebel forces opposing the Syrian Government Forces (SGF) of the Assad regime[9] needed concealment from surveillance and protection from conventional as well as chemical air and artillery strikes[10]. In addition to the civil war, Syria has been the epicenter of the conflict between al-Qaeda[11] and its renegade affiliate the Islamic State of Iraq and Syria referred to as Da'esh[12, 13]. These terrorist groups needed protection from the U.S. led coalition Combined Joint Task Force – Operation Inherent Resolve (CJTF-OIR) air campaign starting in August 2014. These Syrian rebels and terrorist groups fought, and continue to fight against regular forces with superior technology and air superiority[14]. Second, rebel forces and terrorist have been able to exploit both shallow and to a lesser extent, deep subterranea because the regional geology and hydrogeology[15] is favourable to tunnelling, there was local knowledge, and they accepted very high risks associated with going underground. This latter point enabled knowledge, skills and experience to advance rapidly. Third, the oil, gas, quarrying and construction sectors in the region had a large amount of plant, machinery, as well as expert and experienced labour that could be redeployed, adapted and used for subterranean

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7 Daphne Richemond-Barak, *Underground Warfare.* (Oxford University Press, 2018), p. 270.

8 With inter and intra dependencies through, across and within sectors, networks and domains.

9 The Free Syrian Army (FSA), Sunni Arab rebels, Salafi jihadists and Da'esh.

10 Iran, Russia and Hezbollah support the Syrian government.

11 Al-Qaeda operates as a network of Islamic extremists and Salafist jihadists. The organisation has been designated as a terrorist group by the United Nations Security Council, NATO, the European Union, the United States, China, the United Kingdom, France, Russia, India, Turkey and various other countries.

12 Da'esh (ad-Dawlah al-Islamiyah fil-Iraq wa ash-Sham) also known as IS according to the UN Security Council Resolution 2368 (https://www.undocs.org/S/RES/2368(2017)) and the sanctions list (https://www.un.org/securitycouncil/sanctions/1267/aq_sanctions_list).

13 By April 2013, tensions between AQ and IS heightened when the Da'esh caliph Abu Bakr al Baghdadi instructed his fighters to expand from Iraq to Syria to reclaim control over Jabhat al-Nusra. Over the summer and fall of 2013, IS's aggressive posture toward other jihadists led to heightened tensions, which escalated into infighting in January 2014 and ignited the so-called jihadi civil war. The following month, al Zawahiri officially expelled IS from his AQ network.

14 Turkey supports the Syrian opposition but has also opposed the US led support to the YPG fighting Da'esh due to its designation as a terrorist organisation.

15 The branch of geology concerned with water occurring underground or on the surface of the earth.

excavations[16]. This was seized by Da'esh and affiliates and they worked fast to set up and run a large tunnelling programme across the so called 'caliphate'.

In this paper, the use of subterranea by terrorists groups and rebels in Iraq and Syria from 2011 to 2021 is examined. One of the challenges to preparing it has been the difficulty in determining place names, especially when dealing with small towns that may have two or three names, in Arabic, Kurdish, Turkish or Syrian. Reports from Iraqi, Kurdish and foreign media often used culturally specific names. In addition, coverage was often specific to Iraqi, Syrian, Turkish or CJTF forces, Kurdish Peshmerga, local militia, ethnic or religious groups.

Standardisation has been attempted here by cross-reference to multiple sources such as official geology and administrative maps for Iraq, Syria, and the Kurdish Regions.

2. Methodology

Resolutions sufficient to search for evidence of subterranean excavations in Iraq and Syria, that were reported in open source international media, were examined using publically released hand held images, drone footage, as well as EO NASA and ESA satellites such as OLI on Landsat 8, Sentinel-2A, and DigitalGlobe World View. The Operational Land Imager (OLI) on Landsat 8 measures in the visible, near infrared, and short wave infrared portions of the electromagnetic spectrum. The satellite has a 16-day repeat cycle with an equatorial crossing time of 10:00 a.m GMT +/- 15 minutes. Sentinel 2-A images are acquired with a 20.6° field of view providing an approximately 290 km swath, and the equatorial repeat cycle of each Sentinel-2 sensor is 10 days, and five days when combined. Sentinel 2-A uses 13 spectral bands, from the visible and near-infrared to shortwave infrared at resolutions from 10 to 60 m on the ground. DigitalGlobe's WorldView-2 satellite has a revisit time of 1.1 days and provides 0.46 m panchromatic (B&W) mono and stereo satellite image data. WorldView-3 satellite has an average revisit time of < 1 day and provides 31 cm panchromatic resolution, 1.24 m multispectral resolution, 3.7 m short wave infrared resolution (SWIR) and 30 m CAVIS resolution.

16 Mark Bulmer, "Using EO to understand the significance of cement production infrastructure in the Syrian conflict", in *Advances in Remote Sensing of Infrastructure Monitoring.* (Vern Singhroy, ed, Springer Remote Sensing/Photogrammetry, Springer Nature, Switzerland. Chapter 14, 2021). pp. 307-354.

The factors of shape, size, shadow, tone, associated features and movement in images were used to interpret features related to subterranean excavations, characteristics and activities (Hamshaw Thomas, 1920). Shape was used to identify characteristic lines, symmetry and spacing of subterranean structures. Sizes of tunnels and underground facilities (UGFs) such as tactical and storage sites were used to gain insight into their role and capability. Shadows associated with lighting were used to calculate their heights and shapes. The tone within any one image was unique and provided information related to weather, time of day, season, an objects surface and the relative position of the sun if it was taken on the surface. This was harder to use with images taken underground. Tone proved to be useful for tracing cables and on occasion conveyor belts on tunnel walls and floors, as well as distinguishing between subterranean structures in different locations within and between different theatres of conflict. Associated features were often critical to interpreting the function of facilities within tunnels and UGFs. Signature equipment allowed distinctions to be identified between different terrorist and rebel groups excavating subterranean structures, occupiers and users, and their methods. Evidence for camouflage, concealment and deception techniques used to hide tunnel entrances and portals as well as spoil were identified.

2.1 Geospatial Data Analyses. Subterranean structures identified using open source hand held images, drone footage, as well as EO imagery, were geo-located into GIS layers to enable analysis. Identified tactical tunnels and UGFs were analyzed using activity[17], temporal[18], and/or trend analysis[19], and change detection[20] to determine function, serviceability and operational signatures. Where identifiable,

17 In the activity analysis ground-based, drone and satellite images were used to identify, assess and evaluate single or multiple occurrences which indicate subterranean activity is either underway or has taken place. The analysis was determined using a single image to determine if an excavation was active, or multiple images over a period of time, perhaps to assess the movements of spoil and shoring during on-going excavations.

18 Temporal analysis refers to the image sensor return/repeat time between acquisitions and the analysis of that imagery. For satellite imagery this frequency of imaging could be carried out by the same platform or a second one and is therefore another enabler of change detection. Using EO satellites, the return/repeat times were varied and the analysis covered both months and year long period of time.

19 Trend analysis was used in the evaluation and synthesis of activity, temporal and change detection analysis, to identify patterns of activity at subterranean sites to predict likely future trends and outcomes with a particular focus on the irregular or abnormal. The production of spoil over the construction cycle and operation was examined.

20 Change detection was used to compare two or more images to recognise often subtle changes in perhaps the positioning of spoil or equipment through to the differences observed during the construction of a tactical tunnel or UGF, or during its operational use.

factors of shape, size, shadow, tone, associated features and movement in images were then used for dimensional analysis to derive associated metrics that were related to imaged evidence of a tactical tunnel or UGF being operational (e.g. height and diameter were used to determine whether occupants crawled, crouched or stood) and how spaces were used (such as feeding, sleeping, storage). Calculations of excavated volumes were determined from the dimensional analysis and using numbers derived from open source tunnel excavation documentation it was possible to obtain advance rates.

3. Military Subterranea in Syria and Iraq

Rebel forces and terrorist groups have used subterranea in Syria and Iraq as a core part of their tactical, operational and strategic control over urban and rural territories and their military capability. Since the start of the Syrian Civil War in 2011, natural, engineered, mined and hybrid[21], tactical subterranean structures has provided protection to rebels plus terrorist groups against SGF barrel bombs and artillery as well as Russian and Iranian munitions. Offensively, tactical tunnelling has been undertaken to get under critical buildings of military significance to blow them up[22, 23] (Fig. 1), This tactic has been used effectively in Iraq, Syria, Afghanistan, Lebanon and Gaza with associated tunnels being often short, shallow and rudimentary. In Syria, this prompted counter tunnelling by SGF using knowledge gained by Hezbollah from the Lebanon-Israel war where they received North Korean assistance[24]. Once frontlines between opposing rebel, terrorist and government forces became established, subterranean activity transitioned to creating defensive positions. Over time to counter attacks by government forces, rebel and terrorist subterranean structures went deeper enabling long-term survival underground. Complex tunnel networks less than or equal to 20 meters below ground were created by both rebels and Da'esh, along with other terrorist groups using hand tools, power tools and machine excavators. To avoid detection, tunnel

21 A combination of all four.

22 U.S. Finds Clues in Bakery to Foil Iraqi Terror Plot (The Associated Press, 8 Sep 2008). https://www.nbcnews.com/id/wbna26611968. (Accessed 10 Sep 2021).

23 In May 2014 the Islamic Front tunnelled under and destroyed the Carlton Hotel in Aleppo that government forces were using as a base. In March 2015, the Air Force Intelligence building in Aleppo was destroyed in the same way.

24 Yaakov Lappin, "Security and Defence: The North Korean Connection, "(12 March 2016), The Jerusalem Post, available at http://www.jpost.com/Arab-Israeli-Conflict/SECURITY-AND-DEFENSE-The-North-Korean-connection-447557 (accessed 6 Nov 2020).

excavations started in buildings and spoil was hidden in rooms. Tactical tunnels less than 20 meters below ground range from large enough for one person to crouch in to those large enough for three fighters to stand in shoulder to shoulder. In September 2017, a tunnel complex in Raqqa captured from Da'esh was found to be constructed with prefabricated reinforced concrete forms[25] (Fig 2a) similar to those in tunnels in Gaza (Fig. 2b, c). The most sophisticated tunnel complexes had dormitories, mosques, hospitals, armouries, kitchens, latrines, and command centres complete with CCTV, solar panels, computers, phones, electricity, respirators and ventilation. These were serviced by transformers, converters and diesel engines facilitating underground occupation for long periods. These are very similar to Viet Cong tunnel complexes[26] and enabled fighters to come up onto the surface behind, in flanking positions, or amongst advancing forces, achieving great military effect. SGF have attempted to siege and starve rebel and terrorist-held urban areas. In response, tunnel trade became critical for rebel forces, terrorist groups and civilians such as in the Damascus suburbs of the eastern Ghouta enclave[27] reminiscent of the Rafah crossing and Gaza. Rebel forces and terrorist groups tunnelled in almost all urban areas they controlled. Across Syria and Iraq they also exploited existing natural sinkholes, caves, tunnels and quarries. Caves and natural tunnels used by locals for shelter, storage, or religious practices quickly became known to Da'esh after they took over any territory[28]. Outside Mosul Da'esh used the abandoned two point five kilometer long civil infrastructure rail tunnel for a military training site, setting up a shooting range, obstacle course, mosque and clinic within it[29]. This rail tunnel south of Mosul was excavated in the early twentieth century for the Baghdad railway. In northern Iraq, as part of their terror tactics against Iraqi and Iraqi-Peshmerga forces as well as civilians, sinkholes and

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[25] Tunnel form is a formwork system that allows the constructor to cast walls and slabs in one operation in a daily cycle. It combines the speed, quality and accuracy of factory/off-site production with the flexibility and economy of in-situ construction and is recognised as a modern method of construction. The system creates an efficient load-bearing structure.

[26] Tom Mangold and John Penycate, *The Tunnels of CuChi.* (Berkley Books, New York, 2005), p. 299.

[27] At times the same forces fighting each other on the surface were trading with each other through tunnels.

[28] Mark Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq", in *Military Aspects of Geology: Fortification, Excavation and Terrain Evaluation*. (Edward Rose, Judy Ehlen & Ursula Lawrence, eds, Geological Society of London Special Publication. 473, 2019). https://doi.org/10.1144/SP473.11

[29] Isabel Coles, "Mosul Train Tunnel Reveals Assault Course for Elite Islamic State Fighters". *Reuters*, (6 March 2017), https://www.reuters.com/article/us-mideast-crisis-mosul-tunnel/mosul-train-tunnel-reveals-assault-course-for-elite-islamic-state-fighters-idUSKBN16D0WW (accessed 14 November 2020).

caves around Sinjar, Mosul and Tikrit[30] were used by Da'esh as execution sites and mass graves[31, 32]. Over the time of IS occupation, most of the victims executed at mass grave sites were Shiites, Yazidis and Christians, all of whom Da'esh consider to be apostates. The Khasfa sinkhole eight kilometers south of Mosul was 400 meters deep and Da'esh filled it with an estimated 4000 bodies many of which were reported to be Iraqi soldiers and police that surrendered when Mosul fell to Da'esh[33]. In Syria, a similar pattern of mass graves occurred at sites such as near Dera'a as part of Da'esh terror tactics. The al-Hota sinkhole outside Raqqa[34] may be one of the larger mass graves filled with captured Syrian Army soldiers, rebels and jihadists opposed to Da'esh, hostages and civilians, but the number of bodies is unknown. Da'esh used water as a weapon using the kārēz[35] underground irrigation system to control water but also to fight tactically in ways similar to the mujahedeen in Afghanistan[36]. Control of water by Da'esh has been significant in recruiting new Da'esh fighters locally and gaining legitimacy[37]. Subterranea has also been used by Da'esh to destroy or loot items of cultural heritage[38] which have then been used to raise revenue[39].

30 Mark Bulmer and Archie Walters. "The Socio-Cultural and Environmental Impact of Islamic State Use of Sinkholes and Caves as Mass Graves in Syria and Iraq". *13th Spatial Socio-Cultural Knowledge Workshop, Cranfield University.* (12 May 2021). pp. 17.

31 Loveday Morris & Mustafa Salim" ISIS dumped bodies in a desert sinkhole. It may be years before we know the full scale of the killings". *The Washington Post*, (2 March 2017). https://www.washingtonpost.com/world/middle_east/isis-dumped-bodies-in-a-desert-sinkhole-it-may-be-years-before-we-know-the-full-scale-of-the-killing/2017/03/02/0a4c0fd4-fd2b-11e6-9b78-824ccab94435_story.html (accessed 11 November 2020).

32 There is no definition of the term 'mass grave' in international law; it is commonly understood to refer to a site containing a multitude of buried human remains. Under Iraqi national law, 'mass grave' is defined as "land or location containing the mortal remains of more than one victim, who were buried or hidden."

33 Florian Neuhof, "Horror of Mosul where sinkhole became mass grave for 4000 of Isil's victims". *The Telegraph*, (27 February 2017), https://www.telegraph.co.uk/news/2017/02/25/horror-mosul-sinkhole-became-biggest-mass-grave-iraq/ (accessed 14 November 2020).

34 Nadim Houry with Sara Kayyali and Josh Lyons, "Into the Abyss. The al-Hota Mass Grave in Northern Syria". Witness Field News Type. Human Rights Watch. 4 May, 2020. https://reliefweb.int/sites/reliefweb.int/files/resources/Into%20the%20Abyss.pdf (accessed 10 May 2021).

35 In rural areas the ancient qanat (kārēz) technique of water supply from a deep conduit with a series of vertical access shafts is still used for irrigation, providing cattle with water and for drinking water supply.

36 Lester Grau, *The Bear Went Over the Mountain. Soviet Combat Tactics in Afghanistan.* 780 National Defense University Press, Washington DC, 1996), p. 216.

37 Marcus DuBois King, "The weaponization of water in Syria and Iraq". *The Washington Quarterly* 38 (2016), pp. 153–169.

38 Namak Khoshnaw, "Explore the IS Tunnels. How the Islamic State Group Destroyed a Mosque but Revealed a 3,000 Year old Palace". *BBC News*. (22 November 2018). https://www.bbc.co.uk/news/resources/idt-sh/isis_tunnels (accessed 14 November 2020).

39 Daniel Kees, "ISIS the Art Dealer", *Regulatory Review* (13 April 2020). https://www.theregreview.org/2020/04/13/kees-isis-art-dealer/ (accessed 15 November 2020).

When Da'esh crossed over the Syria/Iraq border in August 2014 and captured the town of Sinjar, Kurdish Yezidi civilian hostages were forced to dig tunnels ten meters below ground in the local limestone rock. Over 70 tactical tunnels less than 20 meters below ground have been identified in the complex below the town. Tunnel excavations were started in buildings where spoil could be hidden in rooms to avoid detection by CJTF Intelligence Surveillance and Reconnaissance (ISR) assets. One tactical tunnel zero point nine meters wide and one point eight meters high, extended for three kilometers. In towns and villages formerly controlled by Da'esh in parts of Nineveh, Erbil and Kirkuk governorates, more than 60 tactical tunnel complexes around ten meters below ground have been identified[40]. These are in addition to those in Anbar, Salah Al-Din, and Diala governorates. Documents found in October 2016, in a tunnel complex 10 meters below ground in Sheikh Amir east of Mosul, revealed written Da'esh operational practices for provisioning tunnels[41]. In November 2016, another large tunnel complex was captured from Da'esh in Karemlash where one tactical tunnel excavated ten meters below ground under St Barbara church, was nine kilometers long. The tunnel has evidence of tool marks from drill bits used in excavation. In Bashiqa, twenty kilometers east of Mosul, ten tactical tunnels excavated by Da'esh were discovered in a complex ten meters below ground. These are more sophisticated forming facilities, some have rooms connected to CCTV on the surface, makeshift hospitals, rest areas, kitchens and weapons storage. Small generators in houses above the tunnel entrances powered lights and fans affixed to the tunnel walls. The urban area of Bazwaia was connected to the outskirts of Mosul by a two kilometre long shallow cut-and-cover (C&C) trench, with a deeper tunnel complex under the town. Spoil from the excavations was stored inside buildings (Fig. 3b) and timber shoring along with steel arches was used in the tunnels lengths which had lighting and ventilation (Fig. 3c).

In northwest Syria, the advance on 20 January, 2018 of Turkish Armed Forces (TAF) with Turkish-backed Free Syrian Army (TFSA)[42] began Operation Olive Branch[43]. Advancing forces encountered extensive military use of subterranea by

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40 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

41 Solar panels would be placed near an entrance to charge smartphones and other devices and a month's worth of food was to be kept in a storeroom. Men should not gather at the entrance or in the open, and entrances were to be concealed in houses.

42 The TFSA formed 30 December 2016 is different to the FSA. The official aims of the TSFA are to assist Turkey in creating a 'safe zone' in Syria. At its formation in A'zaz, it proclaimed itself a National Army. The FSA fought against the TSFA.

43 Operation Olive Branch was a cross-border military operation conducted by the TAF and TFSA in the Afrin Region. The air war and artillery barrages ended as the TFSA entered the city of Afrin on 18 March 2018.

the defending forces with new levels of sophistication in the Syrian conflict. If Afrin in 2012, after SGF pulled out, Kurdish People's Protection Units (YPG) and Women's Protection Units (YPJ)[44], founded in 2011 took responsibility for its defense. Both the YPG and YPJ were light infantry constructs with limited artillery, improvised armoured vehicles, no combat engineers and no airpower. To defend against TAF/TFSA in the newly formed Afrin Region, Kurdish parties (KCK/PKK/PYD[45]) and YPG/YPJ constructed tactical trenches, observations towers (OTs), cut-and-cover hardened tunnels (CCHTs) and underground facilities (UGFs) 10 to 20 meters below along the border between Turkey and Syria and throughout Afrin. These were reminiscent of the Maginot Line[46]. In 2015, the Syrian Democratic Forces (SDF) was established composed primarily of Kurdish, Arab, and Assyrian/Syriac fighters, as well as some smaller Armenian, Turkmen and Chechen forces. The SDF fought under the leadership of the YPG/YPJ. The use of subterranea was a direct response to having no air power, needing to avoid detection and improve survivability against munitions used by the SGF, TAF, TSFA, the Al-Nusra Front[47], and Da'esh plus their affiliates. In north-west Syria, military trenches, OTs, CCHTs and UGFs were constructed in mountains of limestone, sandstones and marls and in valleys in alluvial terraces and conglomerates, lithologies very favourable for digging and tunnelling using hand tools and machine excavators. Once fighting began, these prepared positions were occupied by the SDF. Initially, tactical trenches were unsophisticated but underwent

[44] Turkey recognises the YPG, YPJ and SDF as an extension of the PKK however other nations such as the UK have not proscribed the YPG as a terrorist organisation (https://www.gov.uk/government/publications/proscribed-terror-groups-or-organisations--2).

[45] The Kurdistan Communities Union (KCK) is a Kurdish political organisation that serves as an umbrella group for all the democratic confederalist political parties of Kurds, including the Kurdish Workers' Party (PKK) and Democratic Union Party (PYD). The PKK and all its affiliates are considered as terrorist organisations by Turkey with evidence of deliberate targeting of civilians. NATO refers to the PKK as a terrorist entity. In the United States a case had been made for removing the Kurdistan Workers' Party (PKK) from the State Department's list of Foreign Terrorist Organizations (FTOs) would create conditions for greater security cooperation between the United States and the PKK in the fight against the Islamic State in Iraq and Syria (ISIS) (https://www.lawfareblog.com/case-delisting-pkk-foreign-terrorist-organization). In 2020, the supreme court of Belgium ruled that the PKK was not a terrorist organisation, instead labelling the group as an actor in an internal armed conflict (https://www.brusselstimes.com/belgium/92787/belgian-government-defies-ruling-of-its-supreme-court-on-pkk/).

[46] Joe Kaufmann et al., *The Maginot Line. History and Guide.* (Pen & Sword Books, Barnsley, UK, 2011). p. 308.

[47] The Al-Nusra Front is the official Syrian branch of al-Qaeda made up of Syrian jihadists fighting against the SGF and its affiliates, and CJTF militaries. Its goals were to overthrow Bashar al-Assad's government in Syria and to create an Islamic emirate under sharia law. The tactics of al-Nusra Front differed from Da'esh; whereas Da'esh alienated local populations by demanding their allegiance and carrying out beheadings, al-Nusra Front cooperated with other militant groups and declined to impose sharia law where there had been opposition. Al-Nusra presented themselves as moderate in comparison to Da'esh.

rapid design and material improvements to attempt to incorporate force protection lessons learned from the blast and impact effects of weapons systems[48]. Unlined and unsupported tactical trenches collapsed if an artillery round or missile struck near them, burying defenders. The introduction of concrete and rebar reduced trench collapses and meant that TAF air and artillery strikes on fighting positions had to hit a trench directly. Roofing over the tactical trenches to create CCHTs also concealed the defenders from TAF ISTAR assets and made targeting more difficult. Changing angles, alignment and dimensions in tactical trenches and CCHTs were all measures introduced to advantage the defenders and disadvantage the attackers in face-to-face trench warfare, features reminiscent of the World War I trenches[49, 50]. Within machine excavated tactical trenches five to seven meters deep and three point five meters wide (Fig 4a), reinforced concrete was used to create C&C tunnels one point five meters wide, two meters high with all sides zero point nine meters thick (Fig. 4b). These were then covered with spoil to provide additional overhead protection with firing points[51] (Fig. 4c). In several locations "double-deck" tactical tunnels were constructed. OTs constructed of reinforced concrete (Fig. 4d) were connected to CCHTs and had ventilation, electrical wiring and living areas. These linked to command and control (C2) centers at strategic points. In addition to cut-and-cover techniques, the SDF also constructed UGFs as part of the defense around Afrin using tunneling techniques to increase overhead protection by increasing the depth below ground inside mountain slopes. UGFs incorporated design features such as camouflage and concealment, reinforced portals, defensive hard points and thick burster layers, all features of 1914-18 European trench warfare[52], the 1930s French Maginot Line[53] and the Atlantic Wall[54]. The most sophisticated UGFs had dormitories, hospitals, armories, kitchens, latrines, and command centers complete with CCTV, solar panels, computers, phones, electricity, respirators and ventilation, all of which facilitated underground occupation for long periods.

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48 Mark Bulmer, "Geological Considerations for Military Works in the Afrin Battlespace, Syria", in: *Military Geoscience in Peace and War.* (Aldino Bondesan & Judy Ehlen, eds, Springer Nature, Switzerland, 2021). In press.

49 Simon Jones, *Underground Warfare 1914-1918.* (Pen & Sword Books Ltd, South Yorkshire, England. 2010), p. 288.

50 Peter Doyle, *Disputed Earth: Geology and Trench Warfare on the Western Front 1914-1918*. (Unicorn Publishing Group, London, 2017), p. 285.

51 Mark Bulmer, "Geological Considerations of Military Works in the Afrin Battlespace". (Report to 66 Works Group, 170 (Infrastructure Support) Engineer Group. 20 May 2018a). pp. 32

52 Doyle, "Disputed Earth: geology and trench warfare on the Western Front 1914-1918". p. 285.

53 Kaufmann et al., "The Maginot Line. History and Guide". p. 308.

54 Steven Zaloga, The Atlantic Wall (1), (Fortress, Osprey Publishing Ltd, Maryland, 2007), p. 64.

4. Knowledge, Skills and Experience

A critical part of the learning competition between terrorists and security forces in the use of subterranea is understanding terrorist's intent, but also their capabilities (know your Enemy[55]). Each attack, along with tactics, techniques and procedures conducted by the terrorists (both successes and failures) has to be critically examined by the security forces to identify their own weaknesses or to identify measures, tactics, techniques or technology that can be introduced, in order to counter the changing terrorist threat. The ability of non-state combatants to use subterranea has been enhanced by their improved understanding of geology and geotechnics, advances in deployable civil engineering design and materials, as well as in available power tools. In the contemporary conflicts in Syria and Iraq, these have been available to non-state actors within the battlespaces but have also come in from outside[56]. Access to the underground has been through natural features, or through mines, quarries and by tunneling. Practices and techniques used in military tunnels and UGFs show that knowledge came into Syria from Lebanese fighters and that these in turn had been greatly informed by engineers from North Korea. As the conflict in Syria spread and moved into Iraq, other state actors provided subterranean advice and expertise. The YPG and YPJ and then SDF, gained tunnel experience from the KCK and from fighting against the Al-Nusra Front as well as Da'esh in Kobane and Raqqa. This has led to greater understanding by attackers (CJTF, Russia, and Syrian Army, Iran, Turkey, and Israel) of how to use modern weapons systems against subterranean military targets and by defenders from different terrorist and rebel groups[57] of how to use and design in subterranea to increase survivability. Critical to the defenders has been favorable geology (the marble and gneiss of Afghanistan, the limestones, chalky limestones, and marls of Syria and Iraq) for excavating underground and hydrogeology for avoiding the locations of water tables that cause stability and flooding in underground structures. Combining the evidence for open and covered tactical trenches, shallow and deep tunnels and sophisticated UGFs shows that these non state actors designed, excavated and constructed co-ordinated subterranean structures at a range of

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55 Tzun Tzu, *The Art of War*.

56 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

57 These included Syrian Free Army, Da'esh and affiliates, Al-Nusra Front, Kurdish Peshmerga, YPG/YPJ/SDF, Al-Qaeda and Taliban as well as Hezbollah and Hamas all of whom are currently using subterranean.

depths below ground. These have greatly enhanced their ability to survive[58]. Using small arms and IEDs fighters emerging from subterranea were able to delay, and at times destroy, superior armoured and mechanised forces advancing on their positions and were very effective in urban areas where manoeuvre options for advancing forces where often limited or constrained[59].

5. The Advantage of Subterranea

Subterranea has enabled rebel/terrorist forces to avoid detection from air and space surveillance of modern militaries fighting them. Contemporary conflicts in Syria, Iraq, Gaza, Afghanistan, Mali, and Yemen have demonstrated that one of the ways to overcome high technology weapons and platforms is to seek protection in dense urban environments, in steep rugged terrain[60] and underground[61]. While this is not new and has historical precedent in almost all conflicts[62], what is new is the ability to deliver high precision weapons with a range of munitions and at increasing speeds[63] from sea, land, air and subterranean as well as submarine environments. Added to this list is the technological ability to deliver from space. These advances favor the attacker and require the defender and non-combatants in the battlespace to seek ways to enhance their survivability. The scale over which subterranea has been utilized by contemporary non-state actors and the rate at which it has been exploited has been driven by this need for concealment and protection to survive.

5.1 Survivability

In military environments, survivability is defined as the ability to remain mission capable after a single engagement[64] and for civilians it is to remain alive or continue to exist. Where combatants have sought to hide among civilians in

58 However, their ideology (especially fundamentalists) meant that many fighters, once above ground, fought to the death.

59 Barbaree, "Coordinating Chaos, Integrating Capabilities in Future Urban Combat". in: *Complex Terrain Megacities and the Changing Character of Urban Operations.*

60 Mark Bulmer, "Geological Considerations on the use of MOAB in Achin District, Afghanistan" (PJHQ. 23 Apr, 2017). pp. 15.

61 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

62 Colleen Borley, "Take It, Don't Break It A Megacity Concept of Operations". in: *Complex Terrain Megacities and the Changing Character of Urban Operations*. Benjamin M. Jensen, Henrik Breitenbauch and Brandon. Valeriano eds, Marine Corps University Press, Quantico, Virginia. (Chapter 9, 2019). p. 212-233.

63 E Gardner, "Hypersonic Weapons: Can Any One Stop Them". (16 Oct 2018). https://www.airforce-technology.com/features/hypersonic-weapons-can-anyone-stop/ (accessed 4 Nov 2020).

64 Robert Ball, *The Fundamentals of Aircraft Combat Survivability Analysis and Design*, (2nd Edition. AIAA Education Series, 2003). pp. 890.

urban areas[65] this has resulted in both groups seeking protection during fighting on the surface or when aerial and artillery bombardments occur. These have largely been conventional but have included chemical munitions[66]. This has meant that underground spaces such as natural caves and engineered tunnels and facilities have been used for moving and protecting fighters, fighting, hospitals, smuggling, trade, and protecting civilians. In the case of cities like Mosul, Aleppo, Damascus, Afrin, Raqqa and in the West Bank and Gaza all of these uses could occur within the same underground space over the course of a single day.

Engineering and military survivability covers not just a short duration event but over protracted periods, with all aspects of infrastructure needed to survive and to sustain. There are four main system elements. The first is detectability, which is the inability to avoid audio and visual detection, including by radar. The second is susceptibility, which is the inability to avoid being hit by a weapon. The third is vulnerability which is the inability to withstand the hit and the fourth is recoverability. This fourth is the longer-term processes, after being hit, of damage control, firefighting, capability restoration, escape and evacuation. The conflicts in Syria, Iraq, Afghanistan, Lebanon and Gaza have shown that, depending on the geology, going underground has helped avoid the first three elements whilst the fourth can be achieved through engineering. Engineering survivability is the quantified ability of a system, subsystems, process, or procedure to continue to function during and after a natural or human-induced shock[67]. A system is a regularly interacting or interdependent group of items forming a unified whole[68]. With regard to survivability, even as increased levels of destruction have occurred on the surface during the conflicts in Syria, Iraq, Gaza, Afghanistan, Mali, and Yemen, underground these engineering skills have improved driven by necessity utilizing improvised as well as commercial products and methods to improve survivability.

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65 The World Bank Group, “The Toll of War. The Economic and Social Consequences of the Conflict in Syria” (The World Bank Group, 10 July 2017), http://www.worldbank.org/en/country/syria/publication/the-toll-of-war-the-economic-and-social-consequences-of-the-conflict-in-syria.pp. 148.

66 Conference of the Sates Parties Adopts Decision to Suspend Certain Rights and Privileges of the Syrian Arab Republic Under the Chemical Weapons Conventions. (22 Apr 2021). https://www.opcw.org/media-centre/news/2021/04/conference-states-parties-adopts-decision-suspend-certain-rights-and.

67 The World Bank Group, “Guide to Developing Disaster Recovery Frameworks. Sendai Conference Version”. The World Bank Group, European Union and United Nations Development Programme, March, 2015). p. 88.

68 Alexander Backlund, “The definition of system”. Kybernetes 29, 4, (2000), https://doi.org/10.1108/03684920010322055. pp. 444–451.

In rural areas, subterranean structures are difficult to detect in electro optical (EO) imagery and unlikely to be detected in urban environments without first being identified through other sources. Urban areas augment survivability for subterranean structures by mitigating detectability, susceptibility, vulnerability and enhancing recoverability as a result of all the buildings and infrastructure. Increasing levels of destruction in cities such as Mosul, Aleppo, Damascus, Afrin, and Raqqa over the course of the conflicts led to accumulated rubble, debris, and waste that enhanced underground survivability because detectability, susceptibility, vulnerability were reduced. In contrast, the recoverability of underground structures after being hit decreased as infrastructure of the cities was not repaired (e.g. electricity and water services). Tunnelling ten meters and deeper below ground by rebels, Da'esh and AQ/Al-Nusra demonstrated knowledge of how to survive indirect-fire and air strikes. Penetrator air munitions presented the greatest threat to subterranean structures but needed guiding to target to be effective and minimise collateral damage. To reach a tactical tunnel or UGF, munitions needed to penetrate the roof and floor of buildings at surface level and then below ground through ten meters plus of overhead (burster and cushion layer). This enabled survivability from 150 mm rounds (standard artillery), 240 mm rounds (howitzer), 300 mm rounds (multi launch rocket systems) and possibly 400 mm (sixteen-inch) rounds from howitzers. The size and design of the subterranean networks enabled rebel, Da'esh and terrorist fighters to move away from an area under air or artillery bombardment. In the design of tactical subterranean structures, many have been identified that were self-supporting due to favourable rock quality but others had local or systematic support using wire mesh, metal sets and timbers[69]. With wire mesh, a net was held in place using bolts to stop small pieces of rock falling (spalling) from the side walls or roof. Metal sets (or ribs) with wood blocks were placed against the rock to prevent blocks of rock falling from the side walls or roof. Timbers in the form of poles and flat boards were used to stabilise walls and roof. In some instances these were placed locally but in others whole areas were supported (Fig 3c). To deter airstrikes, close air support, and ground forces advancing on Mosul, Da'esh who had no airpower but some limited drone use, set fire to tires and to oil wells in the nearby Qayyara and Najma oil fields that burned from May 2016 until March 2017[70]

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[69] Gary Hemphill, *Practical Tunnel Construction*. (John Wiley & Sons, New Jersey, 2013). p. 415.

[70] Mark Bulmer *Military use of Environmental Degradation by Islamic State, Southern Nineveh, Iraq*. Scientia Militaria: South African Journal of Military Studies, 46, Nr 1, 2018b. doi: 10.5787/46-1-1228.

to create obscuration. Fires were also started at wells between Bayji and Kirkuk in late September and October 2017. On 20th October 2017, fires were ignited at the Al-Mishraq sulphur plant creating plumes of sulphur dioxide and hydrogen sulphide to impede Peshmerga and Iraqi forces advancing to the tunnel complexes on the southern outskirts of Mosul. Fortunately, winds blew the plumes southward towards Qayyara but respirators found in subterranean structures along with food, fuel, basic water and air handling show that Da'esh was prepared to operate in the environmentally degraded conditions they had created.

6. Fighting Against Subterranea

Examination of the distribution of subterranean structures constructed by rebels and terrorist groups in Syria and Iraq shows them located at major road junctions, overwatching bridges, on high ground, at sites of cultural significance and critical infrastructure. This shows tactical awareness and understanding of the battlespace[71]. While it is possible to identify locations of on-going subterranean excavations due to noise, dust, vibration, spoil and subsidence there are no media reports from Syria or Iraq that government forces found any this way. Radar systems and synchronised electromagnetic wave gradiometers have been used for searches of cross-border tunnels in the Korean De-Militarized Zone, Gaza Strip, and US Southern Border[72] but in Syria and Iraq they were largely found by advancing soldiers. The Russian military trained Syrian and Iranian forces in the use of gradiometers, non-contact explosive device finders, search dogs and induction mine detectors as well as unmanned ground sensors[73]. After artillery bombardment and air strikes, advancing Iraqi as well as Syrian Government forces attempted to deal with threats from subterranean fighters by throwing grenades and burning tyres through portals, down shafts and entrances. However, given their military designs, with changes in tunnel angles, slopes and dimensions[74], this

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71 Ishan Gunduz, The Islamic State of Iraq and Al Sham and Its Urban Warfare Tactics. The Foreign Military Studies Office, Fort Leavenworth, Kansas. (18 April, 2017). p.18

72 Larry Stolarczyk, Robert Trounblefield, & James Battis, "Detection of underground tunnels with a synchronized electromagnetic wave gradiometer", in *Sensors and C3I Technologies for Homeland Security and Homeland Defence IV* (Edward Carapezza, ed, Proceedings of SPIE, 5778, 2005), pp. 994–1001.

73 Jay Akbar, "Robot Army. Russia to Send Robot Army of Deadly Ground Drones into Syria by the end of the Year". *The Sun Newspaper* (23 May 2018). https://www.thesun.co.uk/news/6355152/russia-to-send-robot-army-of-deadly-ground-drones-into-syria-by-the-end-of-the-year/ (accessed 6 Nov 2020).

74 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

was insufficient and also took no account of unarmed civilians in these spaces. Tactical tunnels used by Da'esh, rebels and terrorist groups for route denial, filled with IEDs, often collapsed under the weight of a main battle tank or armoured troop carrier. During defence of urban areas under their control, Da'esh strong-pointed surrounding towns with dense networks of bunkers, tactical tunnels, IED-rigged obstacles, and anti tank guided missile (ATGM) ambush zones. As discussed in section 5.1, obscuration was produced from burning tires and oil wells[75]. At all times fighting against Da'esh there was a constant threat to advancing forces from suicide vehicle borne improvised explosive devices (SVBIEDs) that were fed into the strong point battles[76]. To counter this, advancing Iraqi and Peshmerga forces acquired earth moving equipment to build berms any time they stopped. The rate of ATGM strikes from subterranean structures by Da'esh against advancing MBTs made the Iraqi Army reluctant to push armor further into the urban area, resulting in soft-skinned Humvees advancing without armored support. In Iraq, Kurdish Peshmerga engineers often cleared and then defused IEDs in tunnels they captured but there were not enough of them to meet the scale of the need and to maintain the rate of advance. Bulldozers and wheeled Front Loaders were used to close off tunnel portals but not to make the tactical tunnels safe. From October 2016 to July 2017, subterranean structures were integral to the defence of Mosul city by Da'esh providing concealment and protection against airstrikes, indirect and direct fire. They enabled Da'esh to survive underground against their own self-generated environmental degradation; to attack advancing forces from behind and infiltrate when in static positions. In dense urban areas defensive zones covered contiguous urban blocks with outer neighborhoods honeycombed with prepared fighting positions, caches of explosives and ammunition[77]. Mouse-holes along rows of houses along with subterranean structures enabled rapid movement between buildings concealed and protected from airstrikes, indirect and direct fire. Da'esh fought a battle of movement within neighborhoods, including the re-infiltration of areas cleared by advancing forces. Overall, Da'esh demonstrated effective use of subterranean structures as part of their tactics to separate tanks and infantry from cooperating in the street-to-street fighting. In 2021, the resurgence of Da'esh

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75 Bulmer, "Military use of Environmental Degradation by Islamic State, Southern Nineveh, Iraq".

76 Michael Knights and Alexander Mello. Defeat by Annihilation: Mobility and Attrition in the Islamic State's Defense of Mosul.CTC Sentinel, Combating Terrorism Center at West Point (April 2017). pp. 1-7.

77 Ibid.

in northern Iraq appears again to be utilising subterranea, particularly caves in mountainous areas, and it is to be expected that as well as excavating new sites, they will reclaim tactical subterranean structures and stores that were never found by Iraqi and Peshmerga forces or were blocked off but subsequently never cleared.

Similar to the experiences in Da'esh held cities in Iraq, and to other rebel and terrorist-held cities in Syria, the use of subterranea in Afrin and Northern Syria has made it a hard fight for TAF and TFSA against the SDF, YPG and YPJ. Their response has been to overmatch rebel/terrorist defensive works with weapons systems and to make extensive use of concrete sections to erect walls to protect ground they take[78]. During Operation Olive Branch, CCHTs, OTs and UGFs in the mountains were the primary targets for Turkish fighter jets. Heavy Turkish shelling and airstrikes caused many Syrian Kurdish villagers to flee to natural caves in the mountains complicating the distinction between the use of subterranean structures for military purposes and those being used by unarmed civilians. To counter the air and artillery threat subterranean structures used by the SDF, YPG and YPJ were constructed deeper below ground with thicker reinforced concrete lining. However, it appears that the modification did not occur fast enough to effectively defend against TAF air supremacy, artillery, armour, engineering and logistics[79]. Even so, the use of subterranea by the SDF, YPG and YPJ caused the TAF and TFSA to expend significant military resources. SDF, YPG and YPJ trenches and CCHTs constructed in and around villages, towns and cities in Afrin utilized the existing urban infrastructure, adapting it to create obstacles, blocks, hazards and kill zones. Similar to other cities where fighting occurred in Syria and Iraq, buildings were connected by tunnels[80], allowing defenders to move under protection and without being observed. Some of these same underground structures were used by civilian residents for protection from the conflict complicating the distinction between the use of subterranean structures for military purposes and those being used by unarmed civilians.

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78 Bulmer, "Geological Considerations for Military Works in the Afrin Battlespace, Syria".

79 Ibid

80 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

7. Innovation in Subterranea

By late 2016, tunnel complexes captured from both rebels and terrorist groups demonstrated knowledge, skill and experience in how to excavate in the local rock geology in Syria and Iraq. The capture of two types of improvised tunnel boring machines (ITBMs) in Ninevah Province, one by Kurdish Peshmerga and the other by Iraqi forces revealed a significant and unexpected change in Da'esh's capacity and capability[81] (Fig. 5). These machines could increase the dimensions, lengths and areas of subterranean structures. They could also excavate faster than hostages or paid labour[82]. Using fewer tunnel workers enabled the released manpower to be used for other work such as moving spoil and shoring. Fabrication of tunnel boring machines (TBM's) should not have been unexpected given the engineering and mechanical skills Da'esh and affiliates, rebels/FSA and Al-Nusra have demonstrated in Syria and Iraq making weapons, up-armouring vehicles[83] and the large number of vehicles, parts and workshops they had captured. The improvised small tunnel boring machine (ISTBM) captured by Kurdish Peshmerga[84] from Da'esh had a circular cutting head zero point three meters in diameter[85] (Fig. 5a). Once lowered down a shaft, a tunnel shoulder wide and tall enough to crouch through, or to stand in, could be made using two or three horizontal bores extending between two shafts. An improvised tracked tunnel boring machine (ITTBM) was captured underground from Da'esh by Iraqi forces in November 2016[86] (Fig. 5b). The cutting head diameter is two point one meters and a single bore would produce a tunnel tall enough for a person to stand in and wide enough for a car or pick-up truck (technical) to move in[87]. Both the ISTBM and ITTBM are robust, and well suited to the local rock qualities. The advance rates of ITTBM excavations of 24 m /day calculated using analysis of the cutting head, drive mechanisms and rock quality indicate that starting in Karemlash, Da'esh could have been linked up underground the strong points town of Hamdaniya, Badana and Sheikh Amir

81 Ibid

82 There are reports that Da'esh paid some locals 4000 Iraqi dinar (about $4.65) per day to tunnel.

83 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

84 In the village of Tiskhrab on 24 October 2016.

85 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

86 In a tunnel outside Judaydah al Mufti, Mosul. There was a hidden ramp down to the tunnel 10 m deep below ground.

87 Bulmer, "Geological Considerations of Contemporary Military Tunnelling near Mosul, Northern Iraq".

(southeast of Mosul) within one year[88]. The diameters of the resulting tunnels were big enough to enable technicals and VBIEDs to move under the battlespace to these strong point towns as the battle for Mosul progressed. In Mosul, deeper tunnels bored by ITTBMs were again large enough to move VBIEDs around the battlespace undetected until they appeared on the surface. This along with hidden garages may explain their often sudden appearance. This is significant because SVBIEDs were “momentum breakers” directed by drones and motorbikes most frequently used by Da’esh[89] to blunt Iraqi forces penetrations into the inner city and is a capability that may be used in other conflict areas by terrorist groups.

On 20 March 2018, a series of UGFs around Afrin were captured from SDF, YPG and YPJ by TAF and TFSA. One UGF had a 100 meter long tunnel that linked into additional tunnels off which were dormitories, offices, kitchen, and armoury. These UGFs are constructed with concrete reinforced arches with diameters big enough for vehicles and artillery (Fig. 6a) and one is finished with the appearance of an alternate site of civilian government[90] (Fig. 6b). What distinguished these subterranean structures compared to the tactical tunnels was the time needed to create them. A Bobcat front loader, boom mounted cutting head machine and ITTBM were found at one underground site under construction. These three machines worked together underground; the Bobcat to remove spoil, the header machine with extendable boom arm and rotating cutting head to move around a tunnel face (Fig. 6c), and the ITTBM to bore circular tunnels[91] (Fig. 6d). The ITTBM design is similar to one captured outside Mosul in Iraq suggesting a link in their design heritage. Comparing the two, the ITTBM captured in Afrin is improved over the one in Mosul in its cutting head and design quality. It is demonstrably effective in the soft-rock geology around Afrin. On 24 May 2018 an improvised wheeled roadheader machine (RHM) with a ripping-type cutting head using four rotating discs was captured from rebels in southern Damascus[92].

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88 Ibid.

89 Knights and Mello. Defeat by Annihilation: Mobility and Attrition in the Islamic State’s Defense of Mosul.

90 Bulmer, “Geological Considerations for Military Works in the Afrin Battlespace, Syria”.

91 Ibid.

92 Mark Bulmer, “Improvised Wheeled Boring Machines Captured in Southern Damascus, Syria”. (Report to 170 (Infrastructure Support) Engineer Group, Royal Engineers, Chilwell, Nottingham, 2018b). pp. 17.

8. Tunnelling Programmes

The large number of subterranean structures that Da'esh and its affiliates constructed between 2014 to 2018 throughout the 'caliphate' would have necessitated connecting the logistics involved in the construction of tactical subterranean structure to the wider strategic economic and military activity throughout the 'caliphate' by its 'Ministries'[93]. The same relationship appears true for the construction of subterranean structures in Afrin. These non-state actors have demonstrated geological, mining, tunnelling and engineering expertise. Design and tunnelling methods progressed from hand tools to power tools and then to TBMs and RHMs. Running these subterranean teams at the same time required knowledgeable, skilled and competent project managers. This suggests a subterranean training cadre learning lessons to make larger and more sophisticated subterranean structures. Designs of TBMs and RHMs used by non-state actors are maturing reflecting the scale of the critical need to use subterranea to counter the advantages held by modern militaries[94]. The substantial revenues generated by Da'esh and AQ/Al-Nusra have enabled them to purchase parts and expertise globally either on the open or black market to enable their use of subterranea.

9. Conclusions

Contemporary conflicts in Syria and Iraq have necessitated Syrian, Iranian, Russian and Turkish militaries, and CJTF forces to counter the use of subterranea by rebel and terrorist groups. It seems likely that subterranean experience, practices, and possibly operators, came into rebel and terrorist group-held areas in Syria and into Da'esh controlled Iraq from conflicts in Syria, Gaza, Lebanon, Jordan, Turkey, Afghanistan and the DPRK[95]. Terrorist groups have attracted foreign engineering geology and tunnel engineer expertise to their cause either through salaries, ideology or front companies, similar to attracting skilled oil sector specialists to run oil installations they captured in Syria and Iraq[96, 97]. Lessons and improvements from tactical tunnel and UGF subterranean excavations, structures and uses have now been disseminated back into conflicts in those regions. Subterranea forms part of concealment and survival activities along with night-fighting, use of bad

93 Bulmer, "Military use of Environmental Degradation by Islamic State, Southern Nineveh, Iraq".
94 Bulmer, "Contemporary Military Use of Subterranea, pp.106-113.
95 Cohen et al., "From Cast Lead to Protective Edge".
96 Bulmer, "Military use of Environmental Degradation by Islamic State, Southern Nineveh, Iraq".
97 Mark Bulmer, *Environmental Degradation in the Battlespace.*, in: British Army Review Special Report Culture in Conflict, 2019). pp. 48-61.

weather, smokescreens, environmental degradation, mouse-holing, camouflage and deception, and drones aimed at restoring tactical mobility to the battlefield under conditions of enemy air supremacy. As the Syrian conflict continues, it should be expected that Iranian, Russian, and Hezbollah advisors as well as those from Hamas, Da'esh in Africa[98], the Taliban and ISIS-K[99] will learn the most recent lessons in subterranean warfare and tactics, techniques and procedures used by NATO members, allies and partners. Where terrorist groups have been used subterranean structures as mass graves as part of the terror tactics every effort should be made to document the destruction and contamination and assign attribution. Identifying human atrocity and environmental degradation in caves and sinkholes is possible and can be quantified enabling evidence to be used to counter terrorist legitimacy, messaging and recruiting[100].

NATO forces need to analyse contemporary uses of subterranea (both military, civil and political) within specific environments being exploited by state and non-state actors. This requires a clear lead within NATO roles, structures and commands to derive understanding that must be integrated into doctrine for existing operating environments in air (and space), sea, land and cyber. The impact on NATO force planning of an opposing force, both state and non-state heavily utilising subterranea in littoral, urban[101], mountain[102], desert[103] and cold weather environments[104] should be stress-tested. This requires intelligence and engineer-centric thinking. Concepts as to how NATO forces will operate in subterranea must adapt to continuing urbanisation[105] with much growth being in littoral zones many of which are experiencing the impact of rising sea levels[106]. High prices and

98 Jason Warner and Charlotte Hulme, "The Islamic State in Africa: Estimating Fighter Numbers in Cells Across the Continent, CTC Sentinel, Combating Terrorism Center at West Point (August 2018, 11, 7). pp. 21-28.

99 Frank Gardner. "Afghanistan: Who are Islamic State Khorasan Province Militants (BBC News, 11 Oct 2021). https://www.bbc.com/news/world-asia-58333533. (Accessed 11 Oct 2021).

100 Bulmer and Walters. "The Socio-Cultural and Environmental Impact of Islamic State Use of Sinkholes and Caves as Mass Graves in Syria and Iraq".

101 STANAG 6509/ATP 3.2.1.2 Conduct of Land Tactical Operations in the Urban Environment.

102 STANAG 2643/ATP 3.2.1.3 Conduct of Land Tactical Operations in Mountainous Environments.

103 STANAG 2648/ATP 3.2.1.7 Conduct of Land Tactical Operations in Desert Environments.

104 STANAG 2646/ATP 3.2.1.5 Conduct of Land Tactical Operations in Cold Weather Environments.

105 Presently, more than half of the world resides in cities, and this will rise to 70% by 2045. "Global Strategic Trends – Out to 2045. Fifth Edition", (Strategic Trends Programme, Ministry of Defence, Development, Concepts and Doctrine Centre, Shrivenham, Swindon, 2014). p. 202.

106 Almost half a billion urban residents live in coastal areas, increasing their vulnerability to storm surges and sea level rise. In the 136 biggest coastal cities, there are 100 million people – or 20% of their population – and $4.7 trillion in assets exposed to coastal floods. Around 90% of urban

land shortages[107] are driving civil engineering subterranean development below cities and rural areas with increasing force drivers due to competition, extreme weather and climate change[108]. Greater use of subterranea is being enabled by advances in tunnel boring and subterranean engineering with increasing reliability, precision, cost reductions, and shorter project timelines. These factors and the need to replace aging underground civil infrastructure, along with their supervisory control and data acquisition systems, or in the case of many cities in the Middle East, Asia and Africa undertake sewer, water and mass transit projects for the first time, are driving a rapid rate of subterranean construction innovation. Organised crime continues to demonstrate increasing use of subterranea to enable smuggling of weapons, people, and drugs. In 2018, the US Army estimated there were 10,000 large-scale underground military facilities around the world[109] in addition to all those associated with non-state actors as well as civil engineering projects. Further development of tunnelling machines (large and small), skills and expertise should be expected enabling high precision boring in congested spaces and in technically challenging geological conditions. TBMs and RHMs are increasingly available commercially with a growing market in used machines. Across NATO, embracing and investing in subterranea as an operational space will further enable innovations in survivability against conventional, hybrid[110] and gray zone[111] warfare, the re-emerged threat of chemical, biological, radiological and nuclear attack[112] as well as toxic industrial hazard[113]. It will enable strategic, operational and tactical-level constraints and opportunities to be identified in planning and executing NATO military actions incorporating subterranea both in offense and defence rather than reacting at a tactical level once action is committed.

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expansion in developing countries is near hazard-prone areas and built through informal and unplanned settlements. https://www.worldbank.org/en/topic/urbandevelopment/overview

107 As an example, in London between 2008 and 2017 approvals have been granted for 4,650 basements going down 18 m deep. http://www.dailymail.co.uk/news/article-5703283/Map-reveals-4-650-mega-basements-dug-beneath-London-homes.html (accessed 18 May 2021).

108 "Global Strategic Trends – Out to 2045". p. 202.

109 Matthew Cox, "Army is Spending Half a Billion to Train Soldiers to Fight Underground". *Military.com* (24 June 2018). https://www.military.com/daily-news/2018/06/24/army-spending-half-billion-train-troops-fight-underground.html (accessed 6 Nov 2020).

110 Christopher Chivvis, Understanding Russian Hybrid Warfare. Testimony Presented Before the United State House of Representatives Armed Services Committee (22 March 2017). CT-468. p. 12.

111 Qiao Liang and Wang Xiangsui, *Unrestricted Warfare.* (Beijing: Peoples Liberation Army Literature and Arts Publishing House, 1999). p. 228.

112 "Nuclear Posture Review", (Office of the Secretary of Defense, 2018). https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF. p. 100.

113 Bulmer, "Military use of Environmental Degradation by Islamic State, Southern Nineveh, Iraq"

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Florian Neuhof, “Horror of Mosul where sinkhole became mass grave for 4000 of Isil’s victims”. *The Telegraph*, (27 February 2017), https://www.telegraph.co.uk/news/2017/02/25/horror-mosul-sinkhole-became-biggest-mass-grave-iraq/ (accessed 14 November 2020).

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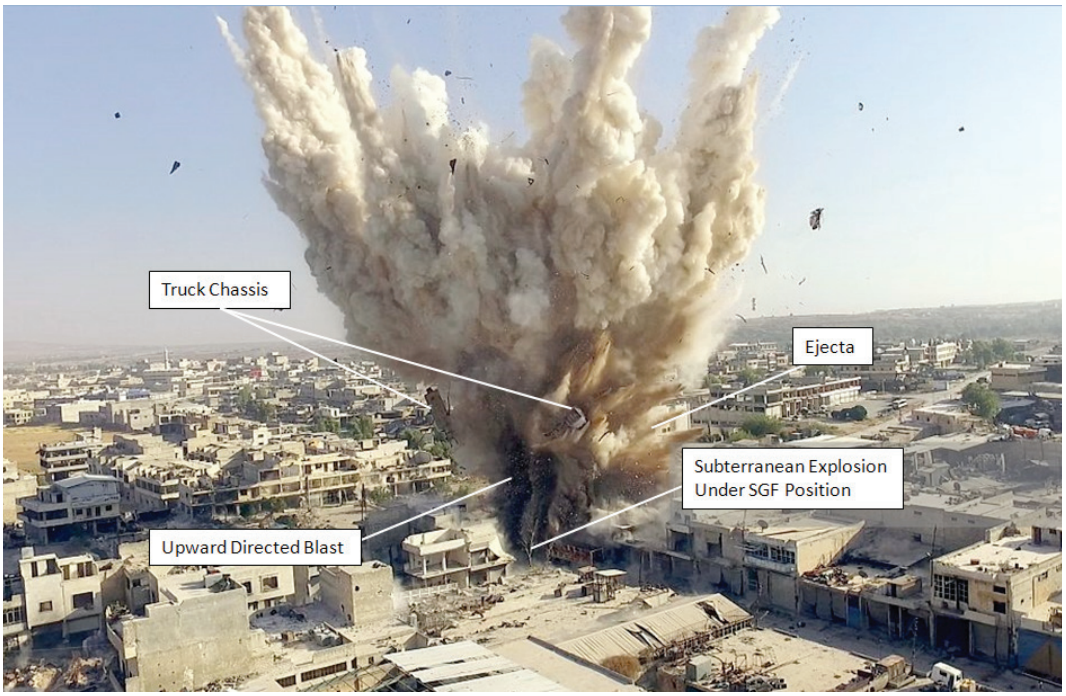

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Figure 2. (a). Tunnel in Raqqa captured on the 5th September, 2017 from Da'esh constructed with prefabricated reinforced concrete[115]. (b). Tunnel in Gaza captured in August 2014[116] with characterists similar to that shown in (a) captured in Raqqa . (c). Tunnel in Gaza captured by IDF Nov 2014[117] showing how concrete forms are used in tunnel lining similar to that shown in (a).

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Figure 3. (a). Covered trench outside Bazwaia, in Ninevah Province with the metal supports and roofing visible that was used as the roofing[118]. (b). Shaft entrance to a tunnel inside a building in Bazwaia[119]. (c). Tunnel below the shaft identified in image (b) showing shoring on the wall and roof as well as power and ventilation[120].

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Figure 4. (a). Defensive trench excavated in the mountains around Afrin in horizontally bedded limestone with marls using a mechanical excavator[121] to be used for SDF, YPG and YPJ fighting positions. (b). Construction by SDF, YPG and YPJ of cut-and-cover hardened tunnels at Sirgaya Hill with the concrete and rebar visible along with form boards placed during the concrete pour[122]. (c). SDF, YPG and YPJ CCHT with multiple firing points and dimensions sufficient for a defender to stand[123]. (d). SDF, YPG and YPJ observation point at Mount Bursaya constructed into the mountain slope and camouflaged with limestone blocks to blend into the surrounding terrain[124].

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Figure 5. (a). View of the front of a captured ISTBM showing the cutting head with Peshmerga fighters for scale[125]. (b). Side view of a captured ITTBM on a flat bed truck with Iraqi soldiers for scale[126].

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Figure 6. (a). Entrance to an SDF, YPG and YPJ underground facility in the mountains around Afrin showing vertical and horizontal rebar wired in a grid pattern ready for concrete to be poured or sprayed[127]. (b). Reinforced room in an SDF, YPG and YPJ underground facility located in the mountains around Afrin containing multiple one hundred meter long tunnels[128]. (c). Front left view of an extendable and multi-axial boom-mounted cutting head machine captured in-situ in a subterranean structure in the mountains around Afrin[129]. (d). Rear right side view of an ITTBM captured in-situ in a subterranean structure in the mountains around Afrin[130].

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