NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-SAS-145**

Soldier Weapon Equipment Assessment Tool: Recommendations for Performance Test and Evaluation

(Recommandations portant sur un outil d'évaluation de l'équipement et des armes des soldats pour l'essai et l'évaluation des performances)

This report documents the findings and recommendations of Research Task Group SAS-145.

Published September 2023

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

AR	Augmented Reality
ARL	Army Research Laboratory
ATAK	Android Team Awareness Kit
CQM	Close-Quarters Marksmanship
DAC	Combat Capabilities Development Command Analysis Center
DEVCOM SC	Combat Capabilities Development Command Soldier Center
FOI	Totalförsvarets forskningsinstitut
GPS	Global Positioning System
IMLF	Instrumented Metricized Live Fire
IW	Individual Weapon
LDS	Lightweight Day Sight
LEAP	Load Effects Assessment Program
LFTT	Live Fire Tactical Training
LOMAH	Location of Miss and Hit
NATO	North Atlantic Treaty Organization
RTG	Research Task Group
SAS	System Analysis and Studies
SCEE	Soldier Combat Effectiveness and Efficiency
SIT	Stationary Infantry Target
STANAG	Standardization Agreement
STANREC	Standardization Recommendation
SWEAT	Soldier, Weapon and Equipment Assessment Tool
VR	Virtual Reality

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Soldier Weapon Equipment Assessment Tool: Recommendations for Performance Test and Evaluation

(STO-TR-SAS-145)

Executive Summary

In order to maintain their technological advantage over potential adversaries, North Atlantic Treaty Organization (NATO) nations are constantly striving to ensure that their Soldiers, Sailors and Aircrew are equipped with the best possible weapons and equipment. In the domain of dismounted Soldiers, this means procuring weapons and equipment that provide Soldiers with maximum lethality, mobility and survivability.

SAS-145 Research Task Group (RTG) explored the requirement to develop a standardized approach to assessing the impact of Soldier, weapon and equipment factors on Soldier Combat Effectiveness and Efficiency (SCEE). Three primary factors were identified as the main contributors to SCEE: Soldier lethality, mobility and survivability. While each of these factors is often examined in isolation, they are rarely examined in concert, meaning that trade-offs and interdependencies between the factors are difficult to assess. In order to bridge this gap, the RTG set out to develop a standardized Soldier-in-the-loop assessment course that would allow Soldier lethality, mobility and survivability to be examined simultaneously. The resulting Soldier, Weapon, and Equipment Assessment Tool (SWEAT) is an operationally relevant, live-fire obstacle course designed to assess the three main contributors to SCEE simultaneously.

The SWEAT concept provides a standardized methodological approach for assessing SCEE that can be used across NATO nations in order to achieve consistency in test standards. The resulting recommendations provide standard definitions for measurements in the area of lethality, mobility, and survivability, along with equipment to achieve such measurements and recommended course of fire. Planning and processing tools are also embedded in the recommendations to allow for adjustments based on range specifications and system being assessed.

By adopting the guidelines set out in this report, NATO members should be able to assess the SCEE of a basic infantry Soldier, i.e., a rifleman, wearing equipment and shouldering an assault rifle. SWEAT may be used to assess other profiles such as a machine gunner, designated marksman, a grenadier, or other roles, although it may need some modification in order to fully address the specific requirements of a given profile. In all cases, SWEAT should be considered as a starting point that can be adapted to meet the specific requirements of the application to which it is being brought to bear. Lastly, SWEAT should not be viewed as the only tool in the assessment toolkit. Although it provides a useful way to assess the impact of a Soldier system on Soldier combat effectiveness and efficiency, it should be employed in concert with other, more focused tests that address specific questions of interest.

The ultimate recommendation is that this standard integrated course should be incorporated into a test and evaluation STANREC for distribution across NATO nations. It is recommended that the SWEAT course is outlined in an official STANREC for distribution and use across the NATO test and evaluation communities. The STANREC should be reviewed periodically by a team of experts to determine whether a follow-on research task group is required for additional development and testing. It is also recommended that scientific validation of the tool be conducted to ensure it is sensitive to changes in equipment configurations at the level required (either within a future NATO activity or elsewhere).

Recommandations portant sur un outil d’évaluation de l’équipement et des armes des soldats pour l’essai et l’évaluation des performances

(STO-TR-SAS-145)

Synthèse

Afin de conserver leur avantage technologique sur les adversaires potentiels, les pays de l’Organisation du Traité de l’Atlantique Nord (OTAN) s’efforcent constamment de s’assurer que leurs soldats, marins et équipages aériens disposent des meilleures armes et équipements possibles. Dans le domaine des combattants à pied, cela implique de fournir des armes et de l’équipement qui offrent aux soldats une létalité, une mobilité et une capacité de survie maximales.

Le groupe de recherche (RTG) SAS-145 a étudié le besoin d’une approche standardisée pour évaluer l’effet des facteurs que constituent le soldat, l’armement et l’équipement sur l’efficacité et l’efficience du combat des soldats (SCEE). Trois facteurs primaires ont été identifiés comme principaux contributeurs à la SCEE : la létalité, la mobilité et la capacité de survie des soldats. Chacun de ces facteurs est souvent examiné séparément, mais leur ensemble est rarement examiné de concert, ce qui signifie qu’il est difficile d’évaluer les compromis et les interdépendances entre les facteurs. Afin de combler ce manque, le RTG s’est fixé pour objectif de mettre au point un parcours d’évaluation standardisé intégrant le soldat dans la boucle, qui permet d’examiner simultanément la létalité, la mobilité et la capacité de survie des soldats. L’outil d’évaluation des soldats, des armes et des équipements (SWEAT) qui en résulte est un parcours du combattant à tir réel, pertinent sur le plan opérationnel, conçu pour évaluer simultanément les trois principaux éléments de la SCEE.

Le concept du SWEAT est une démarche méthodologique standardisée d’évaluation de la SCEE, qui peut être utilisée dans tous les pays de l’OTAN afin d’harmoniser les normes d’essai. Les recommandations qui en résultent fournissent des définitions standard de mesure dans le domaine de la létalité, la mobilité et la capacité de survie et indiquent l’équipement permettant ces mesures, ainsi qu’un cycle de tir recommandé. Les outils de planification et de traitement sont également intégrés dans les recommandations pour permettre des ajustements en fonction des spécifications du champ de tir et du système évalué.

En adoptant les principes directeurs énoncés dans le présent rapport, les membres de l’OTAN devraient être en mesure d’évaluer la SCEE d’un soldat d’infanterie de base, autrement dit un fantassin portant de l’équipement et un fusil d’assaut. Le SWEAT peut servir à évaluer d’autres profils tels que ceux de mitrailleur, tireur d’élite, fusilier ou d’autres rôles, bien qu’il puisse nécessiter des modifications afin de répondre pleinement aux exigences spécifiques d’un profil donné. Dans tous les cas, le SWEAT devrait être considéré comme un point de départ, adaptable aux exigences spécifiques de l’application en question. Enfin, le SWEAT ne devrait pas être considéré comme le seul outil d’évaluation disponible. Bien qu’il constitue un moyen utile d’évaluer l’effet d’un système pour soldat sur l’efficacité et l’efficience du combat, il devrait être employé avec d’autres tests plus ciblés qui répondent à des questions spécifiques.

La dernière recommandation est que ce parcours intégré standard soit inclus dans une STANREC d’essai et d’évaluation pour être diffusé dans tous les pays de l’OTAN. Il est recommandé de décrire le parcours SWEAT dans une STANREC officielle pour qu’il soit diffusé et utilisé dans toutes les communautés d’essai et d’évaluation de l’OTAN. La STANREC doit être revue périodiquement par une équipe d’experts,

qui détermine si un groupe de recherche de suivi est nécessaire pour la faire évoluer et réaliser des essais supplémentaires. Il est également recommandé d'effectuer une validation scientifique de l'outil pour s'assurer qu'il est sensible aux changements de configuration de l'équipement au niveau requis (soit dans le cadre d'une future activité de l'OTAN, soit ailleurs).

SOLDIER WEAPON EQUIPMENT ASSESSMENT TOOL RECOMMENDATIONS FOR PERFORMANCE TEST AND EVALUATION

1.0 INTRODUCTION AND BACKGROUND

1.1 Soldier Weapon and Equipment Assessment Tool Introduction

In order to maintain their technological advantage over potential adversaries, North Atlantic Treaty Organization (NATO) nations are constantly striving to ensure that their Soldiers, Sailors and Aircrew are equipped with the best possible weapons and equipment. In the domain of dismounted Soldiers, this means procuring weapons and equipment that provide Soldiers with maximum lethality, mobility, and survivability. To be able to objectively assess weapons and equipment, standardized laboratory test methodologies have been developed that allow small arms and equipment ensembles to be evaluated (e.g., D14, STANAG 4348, STANAG 4349). The main advantages of these tests include their objectivity and standardization, meaning that tests undertaken by one NATO member are easily comparable to those of another NATO member.

Although laboratory tests like D14 [1] do an excellent job of evaluating key weapon or equipment characteristics, they do not assess the impact of a new piece of equipment on Soldier Combat Effectiveness and Efficiency (SCEE). In order to be effective on the battlefield, dismounted Soldiers (i.e., infantry) must be lethal, mobile and able to survive the engagement. As such, these three factors (lethality, mobility, and survivability) are often viewed as the main contributors to SCEE, with considerable effort being undertaken to optimize Soldier performance along these vectors. Developing standardized tests that assess the impact of Soldier (e.g., training), weapons and equipment factors on SCEE would provide NATO nations with an important tool for evaluating Soldier ensembles. However, existing tests tend to evaluate lethality, mobility, and survivability in isolation. Although each of these aspects of Soldier performance can be evaluated independently, interactions between the three exist. Developing a tool that assesses all three of these areas simultaneously would provide great value to the test and evaluation communities.

To address this gap, the Weapons & Sensors Panel of Land Capability Group Dismounted Soldier Systems of the NATO Army Armaments Group tasked the NATO Science & Technology Organization with investigating the efficacy of having a standardized SCEE assessment tool. The requirements for the tool include consideration of lethality, mobility, and survivability factors simultaneously in order to provide consistent and comparable data to be shared across the NATO countries. This report provides the background and justification to support a standardized course and describes a proposed course that was developed and piloted under the Research Task Group (RTG).

The report describes a dynamic live-fire course known as the Soldier weapon and equipment assessment tool (SWEAT). SWEAT incorporates combat-realistic obstacles and target engagements that permit Soldier lethality, mobility, and survivability to be assessed in concert. The course integrates combat-verified obstacles from the Load Effects Assessment Program (LEAP) protocol [2], samples targets over a range of target distances and arcs of fire and measures the potential degree of Soldier exposure to enemy fire from several firing postures. As such, it includes a variety of factors that are likely to influence SCEE, including fatigue, a range of mobility challenges, challenging target acquisition, and targets ranging from long distance to close quarters. Although SWEAT includes targets at a variety of distances, it is not designed in such a manner as to allow for fine-grained analysis of performance at specific distances. While coarse distinctions in target distance are possible with SWEAT (i.e., close quarters, short, medium, long), for more refined assessments, additional testing designed specifically to address questions of interest are recommended. Likewise, mobility and survivability are assessed at a coarse level in SWEAT. For a more detailed examination of the impact of a Soldier system on mobility or survivability additional more focused tests are recommended. SWEAT is designed to excel at providing an overall assessment of performance that simultaneously evaluates lethality, mobility and survivability using a combat-realistic standardized course.

In its current form, SWEAT represents a first step in the development of a comprehensive Soldier system assessment tool. Although extensive multilateral discussions and limited field testing went into the development of SWEAT, it remains a work in progress, and it is the expectation of this RTG that future iterations of SWEAT will yield an improved course based on lessons learned from earlier implementations. SWEAT represents the consensus view of the RTG and provides a practical way forward for objectively assessing the impact of Soldier, weapon and equipment factors on SCEE.

By adopting the guidelines set out in this report, NATO members should be able to assess the SCEE of a basic infantry Soldier, i.e., a rifleman, wearing equipment and shouldering an assault rifle. SWEAT may be used to assess other profiles such as a machine gunner, designated marksman, grenadier or other roles, although it may need some modification in order to fully address the specific requirements of a given profile. In all cases, SWEAT should be considered as a starting point that can be adapted to meet the specific requirements of the application to which it is being brought to bear. Lastly, SWEAT should not be viewed as the only tool in the assessment toolkit. Although it provides a useful way to assess the impact of a Soldier system on Soldier combat effectiveness and efficiency, it should be employed in concert with other, more focused tests that address specific questions of interest.

2.0 GAP ANALYSIS AND LITERATURE REVIEW

The SAS-145 SWEAT RTG conducted a gap analysis and literature review of all potential methods, measures, and key performance parameters currently in practice that would be relevant to the development and implementation of an integrated assessment of Soldier, weapon and equipment factors on dismounted SCEE. In addition, knowledge gaps in key areas of measurement were considered for future test and evaluation needs. Each area is summarized in the following sections.

2.1 Lethality Measures and Definitions

Lethality methods, measures, and definitions in use across the represented NATO nations were reviewed and summarized for consideration during the development of an integrated SCEE assessment tool. Although there is much overlap in methods, measures and definitions across nations, differences were also identified. For the purposes of this RTG, we define lethality as a measure of the ability of the Soldier in a particular equipment configuration and armed with a specific weapon system to effectively engage targets (i.e., shooting ability). This definition is more akin to marksmanship and less to terminal effects, where the term is also used. In principle, shot data collected as part of SWEAT could be used as an input to lethality models in order to extend the results obtained from the SWEAT course to terminal effects.

Many lethality assessments are developed for testing specific aspects of equipment/weapon performance during specific conditions and as such are often idiosyncratic (e.g., Hamilton et al., 2020 who examined the impact of night vision goggle field of view on close-quarters battle lethality) [3]. However, as equipment/weapon development progresses through the acquisition cycle, more integrative tests that evaluate SCEE are required. The RTG took the position that as a standardized tool for assessing SCEE, SWEAT should incorporate a range of operationally-relevant shooting (from long-range suppressive to short-range combative fires) and assess the marksmanship process in its entirety from target acquisition, through target engagement, to transitioning to subsequent targets. This approach will allow SWEAT to capture critical contributions to performance that can determine the full impact of factors related to Soldier training, equipment, and weapon systems on SCEE.

A variety of measures are used to assess lethality, ranging from quantitative measures of accuracy that look to determine the overall, systematic, and random error associated with lethality (e.g., mean point of impact, group size, mean absolute distance from target center of mass) [4], to categorical measures that look to assess performance related to more operational terms of reference (e.g., incapacitation hits, target hits, suppressive fire), to time (e.g., to engage, to hit, to defeat). The specific measures employed are highly dependent and tailored to the nature of the task/weapon system being examined and the purpose of the test (e.g., research and development or Soldier assessment).

Customization of the test to the equipment/weapon system being assessed and the application for which it will be used are important considerations for an assessment course like SWEAT. Attention should be given within SWEAT to configuring the course to the specific needs of the use case. These may include shifting target distances or removing modules that are not relevant to the system being evaluated.

Standard lethality related definitions of incapacitation and suppression should be leverage from existing NATO publications [5], [6], [7]. Some useful definitions include:

- *Suppression (from AAP-6; NATO, 2018): Fire that [temporarily] degrades the performance of the target below the level needed to fulfil its mission.* With location-of-miss-and-hit targets, suppression can be operationalized as any shot landing within the sensor zone of the target.
- *Target hits: Fire that hits the target degrading its ability to fulfil its mission.* These are typically operationalized as shots landing anywhere on the target.
- *Incapacitation hits (from AEP-4513 page 1-1): Fire that hits the target, rendering it unable to perform its main task.* These are typically operationalized as shots landing within a kill zone on the target (e.g., a 200 mm diameter circle at the target center of mass).

2.2 Lethality Methods, Tools, and Equipment

There are a variety of tools, procedures, and methods available to assess lethality. Many nations develop assessment protocols tailored to their specific needs (e.g., long-distance shooting to assess a sniper rifle), although the measures used to assess performance (quantitative measures of accuracy, categorical measures of effectiveness, time) are typically consistent across nations. When conducting SCEE evaluations, all participating nations agree that Soldier-in-the-loop testing must be conducted. Appropriate research methods and design (e.g., counterbalancing of condition order, sufficient observations in each experimental cell, adequate experimental power) must be adhered to in order to account for and minimize variability from unknown sources and to reduce the influence from sources external to those being examined. Objective measures of performance should be augmented with Soldier-specific data (i.e., demographics, vision testing, handedness, dominant eye, weapon shoulder, experience levels, etc.) and subjective feedback on the task(s) and conditions being assessed. These data can help provide contextual information that complements, caveats and enhances objective data gathered during the evaluation.

A variety of methods were identified for assessing static and moving target marksmanship, including live fire and simulation. Live-fire assessments of static marksmanship were typically conducted using paper targets, pop-up Stationary Infantry Targets (SITs), projected targets or acoustic targets [8], [9], [10]. For moving targets, live-fire tasks varied considerably, depending on the application. Skeet and trap methods were used for shotgun [11], whereas running targets, projected moving targets or targets moving on rails were most common for rifle applications [10], [12], [13].

The target system employed will dictate the comprehensiveness of the lethality data collected. Although paper targets are simple and cheap to employ, they require considerable manual effort to extract shot location, do not provide timing data, and are not reactive. Although they can be supplemented with shot clocks to provide timing data, it can be difficult to synchronize shot times with specific shots. Acoustic targets (e.g., Instrumented

Metricized Live-Fire (IMLF) targets (Saab, Inc.), Location Of Miss And Hit (LOMAH) targets (SIUS Target System USA, Inc.)) are more expensive and require additional infrastructure to employ, but this kind of smart targetry can greatly assist with target presentation and data collection logistics. Targets can be remotely raised and dropped, they automatically record shot location and time of impact, and can be programmed to react to the specific nature of incoming fire (e.g., dropping when suppressed, hit or killed). They can also detect shots that miss the target but that fall within their sensor zone. Other on-weapon and body-borne sensors (e.g., FN Expert/Noptel (FN America, LLC.), SCATT shooting trainers (SCATT USA LLC.), inertial measurement units, etc.) can be used to gather data on aiming behavior, body posture when shooting, and shot counts/timing. Other off-body sensors like infrared gate systems (e.g., FITLIGHT (FITLIGHT Corp.)) can be used to measure Soldier movement and fire position arrival time and time to engage a target.

Because acoustic scoring systems do not provide accurate data for subsonic rounds, U.S. Army Combat Capabilities Development Command Analysis Center (DAC) has also developed a home-grown video scoring protocol that uses a camera system to record hit location data. Similarly, DEVCOM SC has developed an image processing algorithm to automatically extract hit location data and calculate relevant marksmanship measures from pictures of paper targets [14]. These systems compare images from before and after round impact to determine shot location. These systems will score shots in near real time but often require post-processing to validate data. The error of the X, Y data from this system is generally less than 2 cm.

The bulk of the lethality research covered by this literature review examines shooting performance for targets in a 3 m to 350 m range envelope [10], [11], [15], [16], [17]. This upper range is usually considered the maximum effective distance of an individual Soldier using a 5.56 mm caliber assault rifle and SS109/M855 ammunition as is typical of most NATO assault rifles. However, improved bullet design, higher-precision weapons, higher power sights and the possibility of adopting intermediate caliber rounds in the future, requires that any SCEE assessment tool, such as SWEAT, should have the ability to assess performance for targets at longer distances. Research in multiple NATO countries (CA, UK, US) examines marksmanship out to 600 m and in some cases beyond [18], [19]. These efforts have shown that the methods employed for closer target distances can be effectively applied to these longer distances. As such, the SWEAT course is designed to include longer-range targets, beyond 350 m, that push the limits of the Soldier system. Due to typical range size limitations, the SWEAT course may require nation-specific adjustments to accommodate smaller ranges.

Even though live-fire methods were generally preferred for assessing SCEE, more realistic Virtual-Reality (VR) simulators (i.e., Engagement Skills Trainer or EST-2000, Virtual Immersive Soldier Simulator, etc.) that include physical weapons and provide accurate simulations of ballistics and recoil may be viable options for some applications [20], [21]. In addition, Augmented-Reality (AR) systems could be used in the future, although these technologies are still maturing and are not at a sufficiently high technology readiness level to be applied in this domain. Based on the desire that SWEAT be a tool that incorporates lethality, mobility and survivability, and a need to evaluate Soldier, equipment, and weapon factors, the RTG came to the decision that SWEAT must be a live-fire course. Future instantiations of SWEAT should consider whether a transition to VR or AR in part or in full is appropriate.

2.3 Mobility Measures and Combat Obstacle Courses

Mobility plays a key role in SCEE. Fire and movement are critical tactics in the employment of dismounted infantry [22], [23] and is expected to influence SCEE. For the purposes of this RTG, we define 'mobility' using the definition provided in AAP-06: "A quality or capability of military forces [for our purposes, a dismounted Soldier in a particular equipment configuration and armed with a specific weapon system] which permits them to move from place to place while retaining the ability to fulfil their primary mission" (p. 83, AAP-06) [7].

Soldier mobility has long been assessed via combat obstacle courses of varying design. Many NATO nations have invested in the LEAP obstacle course [24]. LEAP was developed to be a standardized, validated, objective measure of load effects on Soldier mobility and came out of extensive reviews of the obstacles encountered by

Soldiers on operations [25]. Assessments of LEAP's specificity and accuracy to assess the impact of clothing and individual equipment on mobility have been conducted by many nations (e.g., Netherlands, Canada, United States) over the past eight years. Based on these investigations, it has been concluded that the LEAP tool is reliable, showing differences across clothing and equipment configurations in the movement strategies employed by Soldiers on the course [26]. Weight is the largest influencing factor in the performance degradations as found across the nations. However, like many other obstacle courses, LEAP only assesses agility and maneuverability, and does not provide an integrated assessment of SCEE in its original configuration.

Given the significant effort invested in the development and validation of the LEAP course, this RTG chose to leverage the work put into LEAP by incorporating many of the obstacles and measurement techniques into the SWEAT course. In combination with the target engagement components of SWEAT, the resulting course aims to provide a more integrated assessment of Soldier performance that includes lethality, mobility, and survivability aspects. Although LEAP remains a useful and more complete tool for assessing mobility, SWEAT aims to provide a more robust assessment of SCEE. In this sense, LEAP and SWEAT are complementary tools, the former providing a detailed assessment of mobility and the latter for SCEE.

2.4 Protection and Survivability Measures of Performance

Military personnel are at risk of serious and incapacitating injuries due to the nature of combat operations. Susceptibility to enemy fire can be mitigated through physical protection (i.e., what we wear) and risk behavior manipulation (i.e., what we do, how we move, etc.) [27]. Military personnel are provided protective clothing and individual equipment to reduce risk, but that can affect tactical movements both physically and behaviorally. Measurements of protection and survivability during combat operations were explored by the RTG to determine if a standard method of assessment would provide value and insight into weapon and equipment effects on SCEE and help define the scope of inclusion within the integrated course.

There are existing computational models that predict survivability, with a focus on the protection that body armor and other materials afford the wearer. These models identify critical anatomy vulnerabilities and predict the ability to survive strikes to those areas based on munition force and protection level of body-worn equipment [28]. These models are intended to be used to estimate survival rate in specific scenarios of enemy fire during modelling and simulation efforts focused on specific materiel solutions for protection. They are also used to determine incapacitation of enemy threats during marksmanship related testing of ammunition and weapon systems.

The other aspect of survivability focuses on susceptibility to enemy fire during tactical movement. Assessment of the ability of military personnel to achieve tactical positions to promote survivability are primarily evaluated through observation, largely due to lack of a standardized method to capture and quantify such behavior data [29]. Previous research has characterized exposure vulnerability, or risk of injury from exposure to enemy fire, through quantifying exposure duration during combat movement [30], [31]. However, only recently have researchers started to quantify susceptibility through a combination of exposure duration and reaction time measurements during enemy combat engagements [29], [32]. Brown et al., (2021) also quantified cumulative bodily exposure area while under cover during combat engagements to understand the risk of incapacitation [29].

Given the trade space between lethality, mobility, and survivability, this RTG believes it is important to quantify survivability behavior within the SWEAT course. During this first iteration of SWEAT, capturing cover position and cumulative exposure at specified course locations required piloting, and measures need further development based on previous research and an examination of the literature.

2.5 Measures of Physical/Cognitive Stress and Physiological Effects

Measurements of stress and physiology were explored as they relate to marksmanship outcomes to see if their addition to the SWEAT course would provide value and additional insight into weapon and equipment effects on SCEE. Shooting behavior is the result of various cognitive processes and is influenced by emotions, specifically anxiety and stress which can hinder (or enhance) performance [33]. Greater levels of stress have been found to interact with cognitive and behavioral functioning [34]. Interventions seem to be beneficial for reducing stress and in some cases can even improve performance [35]. Chronic stress may lead to detrimental physiological changes through allostatic load. Many factors including training play a role in the exacerbation, resilience, and management of stress [36].

During test and evaluation assessments, shooting trials without induced pressure or stress may not produce valid results, resulting in compromised insights into the actual impact a system may have on marksmanship outcomes during operations. For example, Defence Research and Development Canada (DRDC), Totalförsvarets Forskningsinstitut (FOI, Swedish Defence Research Agency), and the Netherlands developed a method to quantify shooting performance on the individual and small unit level [37]. This method included hit probability on standard-sized military targets, incapacitation hit probability and the mean radius of a group of shots at different distances. The results showed that without induced pressure, a logistics unit and an infantry unit produced only minor differences in shooting proficiency. However, as soon as pressure was induced, differences between the units were revealed, with the infantry unit outperforming the logistics unit.

In addition to physical and cognitive effects on behavioral functioning, physiological effects can play a significant role on marksmanship. Most of the literature reviewed demonstrates that fatigue and sleep restrictions have a detrimental effect on cognitive performance (e.g., target discrimination) and response times [38]. However, there were several discrepancies with respect to shooting accuracy. In some cases, the decrements associated with fatigue and sleep deprivation were reduced or eliminated with stimulants (e.g., caffeine) and supplementation (e.g., β-alanine). Additionally, fatigue- / sleep-induced decrements were less apparent in more experienced individuals. It is likely that the discrepancies in the literature with respect to how sleep restriction and fatigue affect marksmanship may be due to differences in testing methodology and experimental design. Little to no research was found on the effects of circadian phase and time of day on marksmanship. The effects of physical strength have been investigated, but mainly on pistol marksmanship (i.e., grip strength on accuracy and weapon handling).

For consistency in test and evaluation, it is recommended that those employing SWEAT monitor or record participant sleep hygiene and fatigue leading up to and during testing. If needed, these factors should be incorporated into statistical analyses to reduce the confounding effects of fatigue or circadian phase shifts. Given the observed effects of inducing pressure, time constraints have been incorporated into SWEAT by limiting target exposure duration. By employing wide arcs, target uncertainty and brief target exposure durations, participants are under significant pressure to successfully find and neutralize targets before they disappear.

2.6 Team Performance Measures and Assessment Methods

Although team performance has been an integral part of armed conflict since the beginning of recorded time, militaries are becoming increasingly dependent on the ability of individual Soldiers to coalesce quickly into effective teams [39]. However, effective team performance is by no means a foregone conclusion when bringing together qualified individuals. It depends on, among other things, team leadership, communication abilities, personality composition, and the ability to anticipate the needs of and adapt to the actions of other team members within a changing environment.

Although using SWEAT to examine the SCEE of small teams (e.g., fireteams, squads, sections) would be desirable, running small teams through a complex, live-fire obstacle course introduces both safety and methodological challenges that were deemed beyond the scope of a first attempt to develop a standardized SCEE course. Future iterations of SWEAT are encouraged to explore the feasibility of expanding the SWEAT concept to include small team performance.

2.7 Rules/Regulations/Safety for Test and Evaluation

There are many nation-specific safety regulations for live-fire ranges. National regulations must be followed, meaning that where SWEAT procedures conflict with these regulations, SWEAT procedures will need to be modified to comply with these rules. In order to facilitate this, SWEAT recommendations provide the flexibility for each nation to adjust the course based on range limitations and safety requirements in order to achieve compliance. When documenting evaluations, deviations from the standard course should be reported.

In addition to safety requirements, each nation must also comply with ethical standards for research and testing involving human participants in accordance with national guidelines (e.g., the *Tri-Council Policy Statement* in Canada*, the Belmont Report* in the United States).

2.8 Literature Review and Gaps Analysis Outcomes

The primary gap in dismounted Soldier, equipment and weapon assessment identified across the NATO nations represented in this RTG is the need for a standardized course for evaluating SCEE. Lethality, mobility, and survivability were viewed as the key factors that needed to be evaluated as part of this effort. Existing lethality tests typically do not include comprehensive mobility components and do not address Soldier survivability. Likewise, mobility courses typically do not include dynamic lethality components and do not typically address survivability either. The goal of the SWEAT effort was to design a standardized assessment tool that addresses lethality, mobility and survivability simultaneously using an operationally-relevant test course designed to measure SCEE.

Although conducting tests that more thoroughly examine lethality, mobility or survivability associated with a new training regimen, equipment configuration or weapon system will continue to be necessary, including a test that can assess lethality, mobility, and survivability simultaneously and in an integrated fashion is desirable. As an integrated tool, it is less likely to miss trade-offs between lethality, mobility and survivability that would be missed by tools that only examine a single factor in isolation. SWEAT is designed to fill this gap and should be viewed as a complement to existing assessment tools and not as a replacement. The data that SWEAT will provide will allow decision makers to examine the lethality-mobility-survivability trade space using an operationally-relevant course, therefore permitting them to make better-informed decisions where it relates to training, equipping and arming the future force.

3.0 SWEAT METHODOLOGY

3.1 Course Overview

The purpose of the SWEAT effort is to assess the impact of Soldier training, weapon, and equipment factors on SCEE using a live-fire obstacle course. Soldier lethality, mobility and survivability were viewed as key contributors to SCEE and are therefore the key performance measures being assessed by SWEAT. To this end, the course is designed to include aspects that reflect each of these components. Firing points with varying degrees of cover are interspersed among operationally-relevant mobility obstacles that the Soldier running the course must traverse. At each firing point, targets at different distances are presented that must be detected and defeated. Performance is assessed by measuring the time to complete obstacles and engage or defeat targets, the degree to which the Soldier is exposed to potential enemy fire during target engagements, and the outcome of those engagements. More detailed descriptions of the measures employed to assess performance on the SWEAT course are provided in Section 4.0

The goal of the SWEAT course is to provide a more realistic and holistic assessment of SCEE under conditions that more closely reflect those experienced during operations. By assessing lethality, mobility and survivability together, on a physically demanding and challenging course, a broader understanding of the impact of Soldier, weapon, and equipment factors can be achieved.

The SWEAT course is made up of a series of eleven firing points as well as a self-defence section, interspersed with five physical mobility obstacles (two walls, two windows and an agility run; see Figure 1) and a variety of prescribed types of movement for crossing ground between firing points (runs, sprints, crawls, bounding rushes). Mobility obstacles were selected from the LEAP course [40]. The LEAP stations had been verified against those faced by Soldiers on recent combat missions and determined to be representative of the types of obstacles encountered during operations [41]. Given the live-fire nature of the SWEAT course, not all LEAP stations were relevant or practical. The sprint, agility run, high and low windows, inner and outer courtyard walls, high and low crawl, and bounding rushes were incorporated into the SWEAT course, while the tunnel and hatch, stairs and ladder, balance beam, and casualty drag were not.

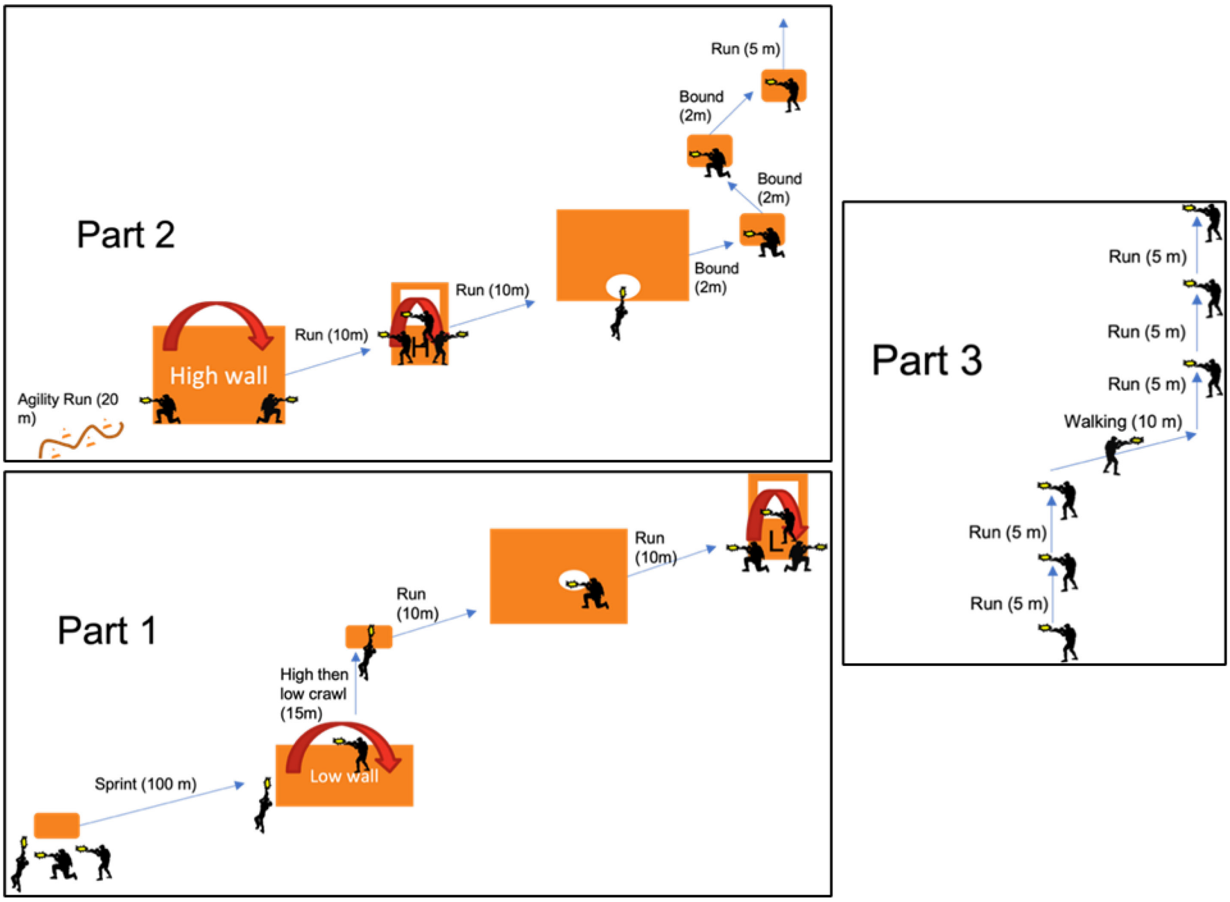

Figure 1: Layout of Obstacles and Firing Positions (Not to Scale). Part 1 (bottom left) shows the beginning third of the course and progresses from bottom left to top right. The course continues in Part 2 (top left), where it again progresses from bottom left to top right. From Part 2, participants move into Part 3 (right), which progresses from bottom to top. The course culminates with a return to the first firing point (bottom left of Part 1) where the first three scenarios are repeated under fatigued conditions. Firing points are indicated by one or more silhouetted Soldiers shooting. The number of Soldiers shooting at each firing point indicate the number of scenarios performed at each firing point, with the posture of the silhouette indicating the assigned posture.

Firing points include sandbags, mouseholes, windows, and walls where the Soldier must adopt a prescribed firing posture and scan for, detect, and defeat targets presented within their arcs of fire. There is a total of 29 target engagements scenarios on the course, with between one and three scenarios at each firing point. Twenty of the scenarios are single-target exposures, while the remaining nine are dual-target exposures. In total, the SWEAT course includes 38 targets.

Shooting scenarios were selected to sample a range of possible engagements. Target presentations progress from long-to-mid-range engagements early in the course, through mid-to-short-range engagements in the mid-course and culminate with a self-defence section containing short-range and close-quarters-marksmanship (CQM) engagements. The course ends with a return to the first firing point of the course where longer-distance engagements are again assessed, this time in a more-fatigued state. This structure parallels the typical course of dismounted engagements on operations where Soldiers initially make contact with the enemy at longer range and close with and destroy them, before reconstituting [22].

At each firing point Soldiers must scan a wide arc for potential targets. As such, Soldiers must first locate the target before engaging it. The inclusion of wide arcs and dual-target scenarios require the Soldier to maintain situational awareness and scan the area for additional targets that may appear after an initial target is presented, potentially at a different depth or lateral position.

3.2 Key Attributes of SWEAT

With only 38 target presentations per run, the SWEAT course is limited in terms of the total number of live-fire observations. Although there are a variety of factors in addition to the SWEAT manipulation (i.e., the Soldier training, weapon or equipment factor of interest) that might be relevant to users of the course (e.g., distance to target, firing posture, use of supports, lateral position of the target, etc.), there are insufficient observations to be able to fully cross them for statistical purposes. However, there are enough observations to be able to examine the interaction between the SWEAT manipulation and some of these factors in isolation. In order to be able to perform these tests, careful consideration was given to the scenarios employed on the SWEAT course. Additional observations were considered, but the RTG identified time to run a trial as a limiting factor that needed to be balanced in order to keep the course at a practical length for reasonable implementation.

Scenarios were designed so that they could be split along four factors that were thought to often be of interest to those who might be employing the SWEAT course:

1) A coarse division based on target distance:
    a) CQM (8 observations);
    b) Short-range (11 observations);
    c) Mid-range (11 observations); and
    d) Long-range (8 observations).
2) The posture of the shooter:
    a) Standing (18 observations);
    b) Kneeling (13 observations); and
    c) Prone (7 observations).
3) The use of supports:
    a) Supported (14 observations); and
    b) Unsupported (24 observations).

4) Single versus dual-target scenarios:
   a) Single-target (20 observations);
   b) First target from dual-target scenarios (9 observations); and
   c) Second target from dual-target scenarios (9 observations).

Not all factors need be included, but there are sufficient observations in each cell of these factors to permit main effects to be examined, as well as the two-way interaction between each of these factors and the SWEAT manipulation, should they be of interest. Higher-order interactions involving these factors are not recommended given the relatively small number of observations per cell that would result.

Performance on the SWEAT course can be summarized for lethality, mobility and survivability for each of the conditions being examined. For example, for lethality, the proportion of targets engaged, hit and defeated can be calculated, either over the entire course, or split based on any of the four factors that the course is designed to assess (coarse target distance, posture, supports and single- / dual-target scenarios). Similarly, the time required to achieve each of these target outcomes can also be examined[1]. Survivability can be assessed by determining the degree of exposure (i.e., body area over time), again across the entire course, or split on any of the factors. Finally, mobility can be captured as the total time to finish the course, or the time to complete the obstacles. Relative performance between conditions can be expressed as a normalized difference (e.g., 20% more targets defeated, 10% less exposed, 15% slower) or in absolute terms (e.g., four more targets defeated, 20 cm^2 less surface area exposed, 15 seconds slower).

Although the SWEAT course provides a means for assessing overall performance in terms of lethality, mobility and survivability using a range of target engagement scenarios and mobility obstacles, it is not a panacea. Where potential users require more detailed information on shooting performance, other tests must be performed to complement the SWEAT course. For example, the SWEAT course does not provide information on shot dispersion, nor does it provide detailed information on the performance of a system at specific target distances. Similarly, although some mobility obstacles are included in the SWEAT course, a tool like LEAP is better suited to examine mobility in isolation, as it includes more obstacles, as well as secondary measures (e.g., range of motion) not included in the SWEAT course. However, the SWEAT course is a good tool for assessing the impact of Soldier, weapon and equipment interventions on SCEE, using key performance measures for lethality, mobility and survivability.

For example, consider a case where the impact of moving to a shorter-barreled rifle was being considered. Course employers could have Soldiers run the course twice, once with the baseline rifle, and once with the shorter rifle. Data from the SWEAT course could be used to assess the impact of barrel length on SCEE along the key parameters of lethality, mobility, and survivability. Furthermore, the effect of barrel length on lethality could be assessed as a function of target distance (CQM, short-, medium- and long-range), posture (prone, kneeling, and standing), use of supports (supported, unsupported) and scenario type (single- versus dual-target scenario). As such, the SWEAT course provides a useful tool for assessing SCEE across a range of measures that are usually examined in isolation. By assessing lethality, mobility and survivability together on an operationally-relevant course, trade spaces can be better understood. Should more detailed data not captured by the SWEAT course be required, companion tests can (and should) be performed.

[1] Time to engage/defeat is complicated by the fact that not all target presentations are equivalent. All else being equal, a system that can engage long-range targets is expected to have a longer average time to engage/defeat than a system that fails to engage/defeat long-range targets because more time is typically taken to engage long-range targets. Similarly, because not all targets will be detected in every condition, statistical tests for some main effects are not recommended due to the insufficient number of observations that are likely to occur in some cells. Assessments of time to engage/defeat should be limited to situations where conditions being compared have achieved a high degree of target engagements/defeats.

3.2.1 Recommended Target Attributes

NATO Figure 11 targets are recommended for all SWEAT targets. Although the use of different targets for different scenarios was considered (e.g., Figure 12 targets, armored targets), in the interest of simplicity the choice was made to include only one target type at this time.

In order to increase the realism of the course and to emphasize the requirement to quickly acquire and engage targets, target exposure times have been limited. As summarized in Table 1, exposure durations increase with increasing target distance and additional time is provided on dual-target scenarios. These times were chosen to, on the one hand induce pressure on Soldiers, while on the other hand leaving sufficient time for a well-trained Soldier to find, engage and defeat the target.

Table 1: Target Exposure Times as a Function of Target Distance and Number of Targets.

Target Distance	Range (m)	Single-Target Exposure Duration (s)	Dual-Target Exposure Duration (s)
CQM	0 – 25	5	7
Short	50 – 100	7	10
Medium	150 – 250	10	15
Long	300+	15	20

In addition to target distance, it is also recommended that targets be distributed across a wide arc laterally, so that the lateral position of targets varies from scenario to scenario. Although this parameter cannot be isolated and formally examined statistically, its inclusion ensures that the target set is more representative of the types of situations that might be encountered during operations. The resulting target-location uncertainty ensures that Soldiers must scan their full arcs both in depth and laterally to locate targets.

For dual-target scenarios, the relative timing of target presentations and the angular separation between targets should be varied. Timings should vary from simultaneous onset to a delay of up to five seconds. Angular separation between targets should vary from relatively small (e.g., 10 degrees or less) to relatively large (40+ degrees). Including target pairs that are more separated in time, depth or lateral position may reveal issues with an experimental condition that might not otherwise be exposed. For example, a high-powered sight may show benefits for long-range shooting, but may also result in attentional tunnelling, where Soldiers miss secondary targets due to the limited field of view of the sight. Choosing target locations and pairings that allow a range of lateral separations to be included is therefore recommended.

3.3 Recommended Layout

Layout will be dictated by ground and logistical constraints. It is recommended that the course be setup in a linear fashion, on flat ground, with the ability to employ relatively wide arcs of fire at each firing point. If possible, a 120-degree arc of fire is recommended for firing points in the middle of the course. One-hundred-and-twenty-degree arcs (equivalent to ten and two on a clock face) are typical of arcs assigned to individual Soldiers in dismounted operations. Targets should be deployed throughout the arc of fire to increase the target-location uncertainty and to encourage proper scanning and maintenance of situational awareness. The use of relatively wide arcs of fire will also permit targets to be used for scenarios at more than one firing point. Reusing targets in this fashion will lower the logistical burden associated with the SWEAT course.

Tools such as Google maps, the Android Team Awareness Kit (ATAK), Handheld GPS units, and laser range finders can greatly assist in planning and setting up the SWEAT course. Pilot testing is always encouraged to ensure good flow of movement through the course and that targets are visible and can be safely engaged from all firing points where they are presented.

A graphical representation of the layout of obstacles and firing positions is shown in Figure 1. The course begins at a sandbag firing point where scenarios 1 – 3 are executed. The participant then completes a 100 m sprint to the low wall (firing point 2) where scenarios 4 and 5 take place. They then go over the wall and high, then low crawl 15 m to a sandbag (firing point 3) for scenario 6. After a 10 m run to a mousehole (firing point 4) scenario 7 transpires. Another 10 m run to the low window (firing point 5) is then executed before completing scenarios 8 – 10. The participant then executes a 20 m agility run to the high wall (firing point 6) for scenarios 11 and 12. Another 10 m run, this time to the high window (firing point 7) for scenarios 13 – 15, follows. Next, the participant runs 10 m to a mousehole (firing point 8) where scenario 16 unfolds. The participant then completes three 2 m bounding rushes to sandbags (firing points 9 – 11), at each of which a scenario is performed (scenarios 17 – 19). The self-defence section of the course follows, with the participant moving forward over 40 m, during which scenarios 20 – 26 take place. At the conclusion of the self-defence segment, the participant runs back to firing point 1, where the first three scenarios are repeated (Scenarios 27 – 29).

A sample, to-scale layout of targets and firing positions is shown in Figure 2. This layout employs twenty targets and is run at a 20-degree slant, meaning that the general direction of movement along the course is 20 degrees from perpendicular to the downrange direction. With this direction of movement, the course requires 250 m of frontage and 400 m of depth. As the slant is increased, the amount of frontage will decrease. However, with too great a slant, down-course obstacles become increasingly likely to fall within the arcs of fire, which could be a safety concern.

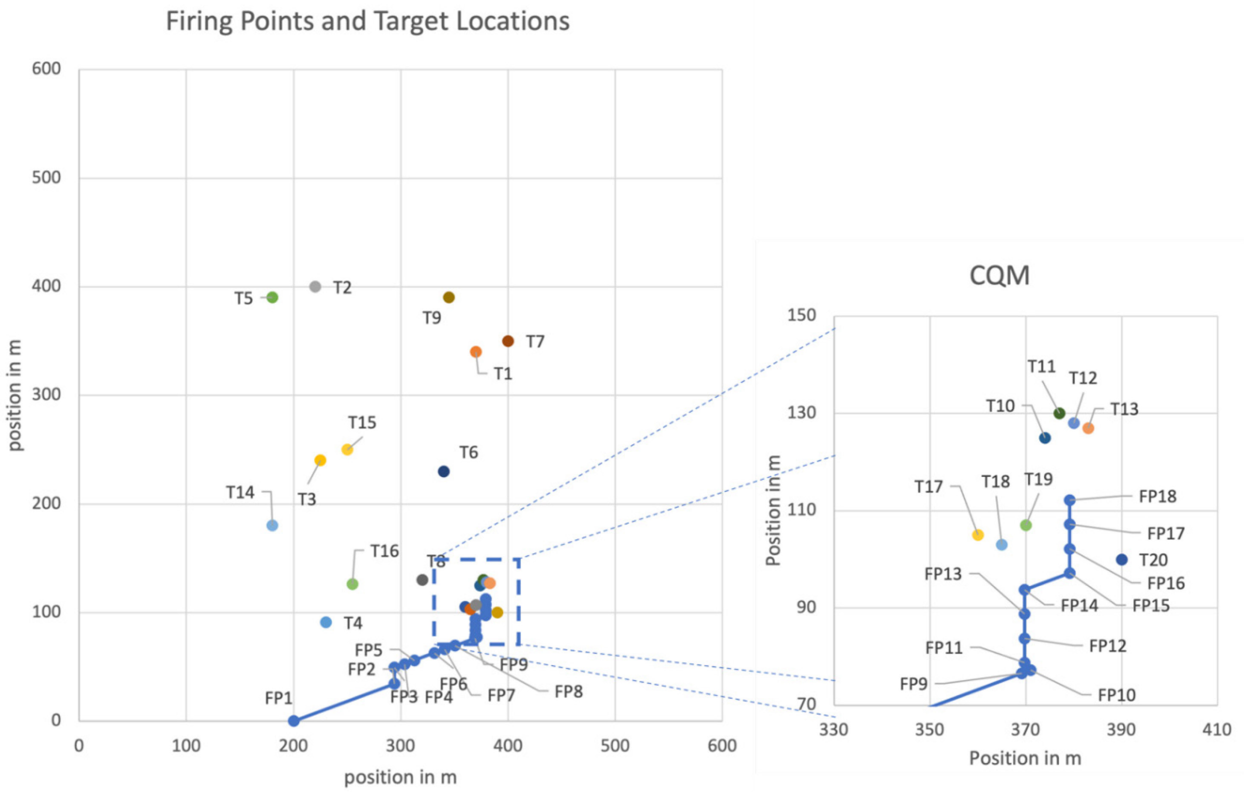

Figure 2: Sample Course Layout. The left panel depicts firing point and target locations. The right panel shows a blown-up view of the CQM portion of the course. The general direction of movement along this course is 20 degrees from perpendicular to the downrange direction. This version of the course includes twenty targets.

A detailed description of the twenty-nine scenarios is provided in Table 2. Distances are provided only at a relatively coarse level (CQM, short, medium, long), to allow sufficient flexibility to accommodate the ground being used for the SWEAT course. When positioning targets, care should be taken to distribute targets throughout the range band, and for dual-target scenarios, that a range of angular separation values be sampled. Alternate scenario sets should be created so that Soldiers do not learn the target presentation scheme. With such an approach Soldiers will be less able to anticipate targets. A within-subjects approach is recommended, meaning that each Soldier participating in the study runs the course in each of the conditions under examination. There should be as many scenario sets as there are conditions so that no Soldier runs the same scenario set twice. Counterbalancing of conditions and scenario set orders across Soldiers is highly recommended to control for order effects.

Two sample scenario sets for the course layout shown in Figure 2 and detailed in Table 2 are presented in Table 3 and Table 4. Although some scenarios are reused across the sets, the combinations of targets used for dual-target scenarios as well as many of the single-target scenarios change between the two sets. The two sets are nonetheless very similar in terms of target characteristics, with an average target distance of 159.7 m for Set 1 and 158.9 m for Set 2 and an average angular separation between targets on dual-target scenarios of 29.4 degrees for Set 1 and 29.9 degrees for Set 2. The addition of more targets will increase the degree of flexibility in creating alternate scenario sets, while increasing the logistical requirements.

3.4 Procedures

Prior to employing the SWEAT course for test and evaluation assessments, proper test planning should occur to ensure consistent execution of procedures across runs. Pilot testing should be conducted to confirm that all data are being captured and that there are no problems with the course layout. Annex B includes a sample test plan from SWEAT pilot testing conducted in the UK, with basic procedures. There are a number of planning considerations when developing a test plan. Including participant familiarization and training runs prior to testing will reduce learning effects that might otherwise contaminate the data. Decisions will need to be made with respect to standardizing non-experimental equipment to be worn by the participants, types of targets, including how they will be controlled, and data extracted (e.g., remote-control LOMAH targets versus pop-up targets), timing mechanisms to capture mobility performance (e.g., stopwatch versus timing gates, versus offline measurement from video), and layout deviations based on either the available range or piece of equipment being assessed. It is important to document all details within the test plan and trial report so that consumers understand the conditions of test employed. More information on capabilities and limitations for the equipment considerations will be provided in Section 4.0. Note that the number of personnel required to run the test procedures will be determined based in part on the level of equipment technology autonomy included (i.e., less autonomy will require greater level of staffing for equivalent throughput of test participants). Care should be taken to ensure that no data collector role is overloaded during the execution of the run. Should concerns in this regard be identified during pilot testing, Additional data collectors should be sought in order to offload some tasks to other data collectors.

Planning tools have also been created and included in this recommendations report for future standardization in methodology execution. The use of layout software is recommended so that the course can be constructed virtually in advance of building it on a range. These types of tools can help with adjustments to the course to accommodate various range sizes and safety requirements and allow for angular distance checks for target placements. As shown in Figure 2, layouts can be created using Microsoft Excel (Redmond, USA), or with more advanced design packages such as Autodesk's AutoCAD (San Rafael, USA). A sample layout planning tool employing Microsoft Excel is included as part of the SWEAT course documentation (Annex C).

A sample data collection sheet and analysis plan that can be used to guide execution and analysis planning is also included in Annex D. The tool is based on the planning of the UK event, discussions at the SWEAT meeting in Toronto in October 2019, instruments used at the DEVCOM SC, and sample data from DAC, as well as discussions during meetings of the SAS-145 Data Analysis and Lethality groups. It is meant to simply be an example guide. In practice, it is assumed to be a bespoke living document.

Table 2: Summary of Scenario Details.

Scenario	Firing Point # (Details)	Posture (Support)	Target(s) Distance	Target Drop Rule
1	1 (sandbag #1)	P(s)	L	5 shots/time
2	1 (sandbag #1)	K(u)	M	5 shots/time
3	1 (sandbag #1)	S(u)	S	5 shots/time
4	2 (left of low wall)	P(u)	L, L	1 hit/time
5	2 (over left wall)	S(s)	L, L	1 hit/time
6	3 (sandbag #2)	P(u)	L, L	1 hit/time
7	4 (mousehole -mid)	K(u)	M, M	1 hit/time
8	5 (low window)	K(s)	S	1 hit/time
9	5 (low window)	S(s)	M, S	1 hit/time
10	5 (low window)	K(s)	S	1 hit/time
11	6 (high wall)	K(s)	S, M	1 hit/time
12	6 (high wall)	K(s)	M, S	1 hit/time
13	7 (high window)	S(s)	S	1 hit/time
14	7 (high window)	S(u)	M, M	1 hit/time
15	7 (high window)	S(s)	S	1 hit/time
16	8 (mousehole-low)	P(u)	M	1 hit/time
17	9 (sandbag #3)	K(u)	M	1 hit/time
18	10 (sandbag #4)	K(u)	S	1 hit/time
19	11 (sandbag #5)	K(u)	S	1 hit/time
20	12	S(u)	CQM	2 shots/time
21	13	S(u)	CQM	2 shots/time
22	14	S(u)	CQM	2 shots/time
23	15	W(u)	CQM	2 shots/time
24	16 (Bill Drill)	S(u)	CQM	6 shots/time
25	17	S(u)	CQM, CQM	2 shots/time
26	18	S(u)	CQM	2 shots/time
27	1 (sandbag #1)	P(s)	L	5 shots/time
28	1 (sandbag #1)	K(u)	M	5 shots/time
29	1 (sandbag #1)	S(u)	S	5 shots/time

Notes:

Posture: P = Prone, K = Kneeling, S = Standing, W = Walking; **Support:** s = Supported, u = Unsupported

Target Distance: CQM = Close Quarters Marksmanship (0 – 25 m), S = Short (50 – 100 m), M = Mid (150 – 250 m), L = Long (300+ m)

Target Drop Rule refers to the conditions under which the target is to drop. In all cases the target will drop when the exposure duration expires if no other rule has been satisfied. With the exception of the first and last three targets which drop after five shots, regardless of outcome, all short-, mid- and long-range targets will drop after one hit. All CQB targets drop after two shots, except for scenario 24 where a Bill Drill is performed (6 shots, center of mass).

Table 3: Sample Scenario Set #1.

Scenario	Posture (Support)	Firing Position	Target 1	Distance (m)	Angle (deg)	Target 2	Distance (m)	Angle (deg)	Angular Separation (deg)	Time Offset (s)
1	P(s)	1	2	400.5	2.86					
2	K(u)	1	3	241.3	5.95					
3	S(u)	1	4	95.8	18.25					
4	P(u)	2	1	315.1	13.96	5	373.6	-17.76	31.72	0
5	S(s)	2	2	373.2	-11.43	7	333.1	18.56	29.99	4
6	P(u)	3	9	344.6	8.52	1	300.6	14.65	6.14	1
7	K(u)	4	15	204.5	-15.13	14	177.3	-44.08	28.95	1
8	K(s)	5	4	89.8	-67.10					
9	S(s)	5	6	176.1	8.90	16	90.7	-39.55	48.44	5
10	K(s)	5	8	74.3	5.59					
11	K(s)	6	3	206.7	-31.03	8	68.1	-9.77	21.26	3
12	K(s)	6	15	204.1	-23.55	10	75.2	34.34	57.89	0
13	S(s)	7	8	67.1	-18.21					
14	S(u)	7	14	197.1	-54.76	15	205.0	-26.34	28.42	4
15	S(s)	7	10	67.4	29.38					
16	P(u)	8	6	160.6	-3.70					
17	K(u)	9	15	210.4	-34.49					
18	K(u)	10	11	53.1	6.46					
19	S(u)	11	12	50.3	11.78					
20	S(u)	12	19	23.2	0.65					
21	S(u)	13	18	15.0	-18.43					
22	S(u)	14	17	14.9	-40.96					
23	W(u)	15	20	11.2	75.55					
24	S(u)	16	10	23.4	-12.69					
25	S(u)	17	13	20.2	11.04	11	22.9	-5.35	16.39	3
26	S(u)	18	12	15.8	3.13					
27	P(s)	1	2	400.5	2.86					
28	K(u)	1	3	241.3	5.95					
29	S(u)	1	4	95.8	18.25					

Notes:

Posture: P = Prone, K = Kneeling, S = Standing, W = Walking; **Support:** s = Supported, u = Unsupported

Distance is the distance between the firing point used for a given scenario and the target in question.

Angles are relative to the downrange direction. Negative numbers indicate left of center. Positive numbers indicate right of center.

Angular Separation is the absolute value of the difference between the angles for Targets 1 and 2.

Time Offset refers to the amount of time between the presentation of Target 1 and Target 2 in seconds.

Table 4: Sample Scenario Set #2.

Scenario	Posture (Support)	Firing Position	Target 1	Distance (m)	Angle (deg)	Target 2	Distance (m)	Angle (deg)	Angular Separation (deg)	Time Offset (s)
1	P(s)	1	2	400.5	2.86					
2	K(u)	1	3	241.3	5.95					
3	S(u)	1	4	95.8	18.25					
4	P(u)	2	1	315.1	13.96	5	373.6	-17.76	31.72	0
5	S(s)	2	2	373.2	-11.43	7	333.1	18.56	29.99	5
6	P(u)	3	9	344.6	8.52	1	300.6	14.65	6.14	0
7	K(u)	4	15	204.5	-15.13	14	177.3	-44.08	28.95	2
8	K(s)	5	4	89.8	-67.10					
9	S(s)	5	6	176.1	8.90	16	90.7	-39.55	48.44	3
10	K(s)	5	8	74.3	5.59					
11	K(s)	6	3	206.7	-31.03	8	68.1	-9.77	21.26	1
12	K(s)	6	15	204.1	-23.55	10	75.2	34.34	57.89	1
13	S(s)	7	8	67.1	-18.21					
14	S(u)	7	14	197.1	-54.76	15	205.0	-26.34	28.42	4
15	S(s)	7	10	67.4	29.38					
16	P(u)	8	6	160.6	-3.70					
17	K(u)	9	15	210.4	-34.49					
18	K(u)	10	11	53.1	6.46					
19	S(u)	11	12	50.3	11.78					
20	S(u)	12	19	23.2	0.65					
21	S(u)	13	18	15.0	-18.43					
22	S(u)	14	17	14.9	-40.96					
23	W(u)	15	20	11.2	75.55					
24	S(u)	16	10	23.4	-12.69					
25	S(u)	17	13	20.2	11.04	11	22.9	-5.35	16.39	5
26	S(u)	18	12	15.8	3.13					
27	P(s)	1	2	400.5	2.86					
28	K(u)	1	3	241.3	5.95					
29	S(u)	1	4	95.8	18.25					

Notes:

Posture: P = Prone, K = Kneeling, S = Standing, W = Walking; Support: s = Supported, u = Unsupported

Distance is the distance between the firing point used for a given scenario and the target in question.

Angles are relative to the downrange direction. Negative numbers indicate left of center. Positive numbers indicate right of center.

Angular Separation is the absolute value of the difference between the angles for Targets 1 and 2.

Time Offset refers to the amount of time between the presentation of Target 1 and Target 2 in seconds.

4.0 SWEAT MEASURES AND TECHNOLOGY

The following sections include the identified measures and recommended equipment, or technology required to run the SWEAT course. Information is provided on equipment options and considerations on capabilities and limitations. The type of equipment selected may have implications on control automation, number of personnel required to run the course, and data processing requirements. With the ever-changing advancements in technology, it is recommended that the research team consider all options and available equipment that may improve the ability to fully capture performance on the course while minimizing the evaluator's burden. It is also recommended that any new test equipment or system is calibrated and assessed for accuracy and consistency prior to use in the SWEAT course.

4.1 Lethality Measures

The goal of the SWEAT effort was to be able to assess SCEE by simultaneously assessing Soldier lethality, mobility and survivability using a realistic, operationally-relevant assessment course. The goal of this section of the report is to clearly define and understand how lethality should be measured and interpretated, from target acquisition, through target engagement, until the point of target incapacitation. As discussed in Section 2.1, in the context of SWEAT, lethality is defined as the ability of the Soldier in a particular equipment configuration and armed with a specific weapon system to effectively engage targets. To break this down further, lethality includes detecting, engaging, and incapacitating threats in a quick and efficient manner.

In order to assess lethality along these axes, SWEAT instrumentation must be able to capture time-locked-to-target-exposure fall-of-shot data. From these data, aggregate measures of lethality can be derived. Specifically, the following measures of lethality are likely to be of interest to those using SWEAT. In all cases, measures of lethality can be assessed broken down as a function of various factors (e.g., the SWEAT condition being examined, target distance, firing posture, etc. See Section 3.2 for additional information on factors that can be examined). Not all measures need be employed, and additional measures not mentioned in this list may also be of interest.

4.1.1 Definitions

Proportion of targets engaged: Operationalized as the number of targets engaged (regardless of shot outcome) divided by the number of targets presented.

Proportion of targets hit: Operationalized as the number of targets hit divided by the number of targets presented.

Proportion of targets incapacitated: Number of targets for which shots fell within pre-defined target incapacitation zones divided by the number of targets presented.

Hit Rate: proportion of shots that hit the target. Operationalized as the total number hits divided by the total number of shots taken.

Time to engage: Time from target exposure onset until first shot.

Time to defeat: Time from target exposure onset until first hit.

Efficiency (hit/incapacitation): Number of shots required to achieve a hit/incapacitation. Operationalized as the number of shots divided by the number of hits/incapacitations.

If desired, fall-of-shot data can be used as an input to lethality models in order to determine the terminal effects associated with shots.

4.1.2 Equipment Considerations

The equipment required to measure lethality includes targets and equipment to capture shot times and fall of shot. There are a variety of target systems that could be used to meet this requirement. At a minimum, it is recommended to have a system that can be controlled remotely for a timed or queued pop-up function. If paper targets are to be used, it is recommended that they be supplemented with shot clocks to capture shot times and that post-processing tools are used to automate fall-of-shot coordinate extraction. The RAMPART tool is an example of an image processing tool that can increase throughput and reduce processing times for extracting fall-of-shot data [14]. Automated target systems like the Saab IMLF are good options for automating target presentation, capturing shot times and fall of shot, and that can be engaged from multiple firing points. Such systems can greatly reduce the logistics and personnel burden associated with implementing SWEAT.

4.2 Mobility Measures

In accordance with NATO AAP-6, integrated mobility within the SWEAT context was defined as the quality or capability of a dismounted Soldier which permits them to move from place to place while retaining the ability to fulfil their primary mission (See Section 2.3). Time between key points in the course has been identified as the primary means to capture mobility. These are shown graphically in Figure 3. Increasing technology autonomy would allow for more refined timing segmentation and allow for additional insight into test configuration effects on additional aspects of maneuverability performance. Observed trips and falls could be used to supplement mobility timing data.

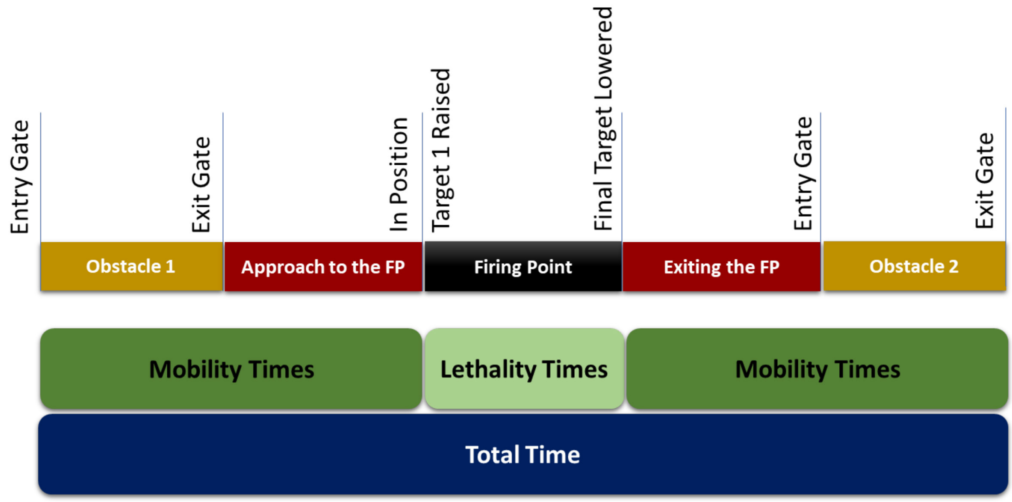

Figure 3: Timing Segmentation. This visualization depicts the timing segmentation for lethality and mobility related timing measurements.

4.2.1 Definitions

Obstacle Time: Time to traverse each obstacle from obstacle approach to obstacle completion based on defined locations for the beginning and the end of the obstacle (i.e., the entry and exit gate in Figure 3).

Firing Point Entry Time: Time from completion of the previous obstacle until the Soldier is in the correct posture at the subsequent firing point. The end point of this time period coincides with the beginning of the firing point time (see next) and the raising of the first target at the firing point. The determination that the participant is in the correct firing posture to begin the scenario is made by the data collector, who signals the target operator to begin the scenario.

Firing Point Time: Time from the raising of the first target until the last target for the firing point is lowered.

Firing Point Exit Time: Time from the last target for the firing point being lowered until the Soldier reaches the beginning of the subsequent obstacle.

Overall Course Time: Time to complete the entire SWEAT course, which will equal the sum of all obstacle, firing point entry, firing point and firing point exit times.

4.2.2 Equipment Considerations

The equipment required to measure mobility include physical obstacles, markers, and equipment to capture time segmentations. The use of spray paint or flags to mark the course is recommended in order to clearly indicate to the Soldier running the course the route that must be taken. Markers at each firing point indicating where the participant needs to go and what posture they should adopt are also recommended. Timings can be taken in real time with a stopwatch or app, or the runs can be recorded so that timings can be extracted after the fact. Regardless of the method used to acquire timings, clear markers indicating and/or rules governing the beginning and end of obstacles are required (entry and exit gates; see Figure 3).

The physical obstacles used as part of the SWEAT course are all drawn from the LEAP system. The low and high window and the low and high wall obstacles are included. In addition, the agility run, bounding rushes, high and low crawl, and sprint obstacles are included in the course. Additional cover structures beyond those drawn from the LEAP system include two walls with mousehole shooting positions. Low window obstacle should measure approximately 5’ (w) x 10’ (h) x 8” (d) with an exact 36” x 36” window cut-out, with a bottom ledge situated 4’(h) from the ground. A landing platform on the opposite side of the window cut-out should measure approximately 5’ (d) x 5’ (w). The high window obstacle should measure approximately 5’ (w) x 10’ (h) x 8” (d) with an exact 36” x 36” window cut-out, with a bottom ledge situated 5’ (h) from the ground. A landing platform on the opposite side of the window cut-out should measure approximately 5’ (d) x 5’ (w). The surface of high window obstacle should be covered with a textured resin and 3 toe holds (all protruding) should be placed on the approach side to aid a person in mounting the obstacle. The low wall obstacle should be approximately 8’ (w) x 4’ (h) x 6” (d). The surface of the wall should have a smooth surface (paint only is suggested), and no toe holds should be present on this obstacle. The high wall obstacle should be approximately 8’(w) x 6’(h) x 2’(d) with a landing platform on the opposite side measuring approximately 5’ (d) x 8’(w). One of the obstacle walls should be textured resin surface containing no less than 9 toe holds (5 protruding, 4 receding) on the approach side to aid a person in mounting the obstacle. Additional specifications for the obstacles and cover structures can be found in the LEAP equipment manual [40].

Time to traverse obstacles and segments of the course will be captured using either automated sensors (i.e., timing gates, IR sensors, pressure sensors, RFID sensors, etc.) or manual equipment (i.e., stop watches). If course timings are to be extracted after the fact, a reliable and comprehensive method for record each run will be required. Specialized, custom applications can be used instead of paper and pencil, and stopwatches to record time events. These applications can be programmed to present a running clock, and the listing of the events in sequence (entering an obstacle, exiting an obstacle, in position at the firing point, times of shots, departing the firing point, etc.). When the event occurs, the data collector touches the button or screen to mark the event. At the conclusion of the run, the app would output a list of all events and the times at which they occurred. A sample timing app is included as part of the SWEAT documentation (see Annex E). In addition to determining which equipment fits the need of your test/organization, synchronization of your selected equipment will need to be considered. Instrumentation may require specialized equipment, cables, power, and computers to record the data and may require weatherproofing.

4.3 Survivability Measures

Survivability within the SWEAT context was operationalized as the amount of tactical cover achieved by the participant while engaging in tactical shooting. Specifically, integrated survivability within the SWEAT context was defined as the ability of the Soldier to limit vulnerability through bodily exposure to threat in order to minimize enemy targeting when the Soldier is engaging targets. The primary measurement of interest is the cumulative exposure area across time, or the integral of exposure area. Time between locations of cover were considered mobility measures for this course but could be considered a form of survivability or protection. It is important to note that the minimal viable product of the SWEAT tool will not assess survivability in terms of what the protective equipment affords. Future iterations might plan on incorporating various calculations of survivability based on body armor and personal protective equipment coverage.

4.3.1 Definitions

As described by Brown et al. (2021), survivability measures in SWEAT include the following [29]:

Duration of the exposure: Time from initial exposure of Soldier to potential enemy fire during the engagement (i.e., appearance of participant in camera's frame). This can be segmented into duration between the initial exposure to initial shot, the final shot, or duration between the initial and final shot measured in seconds(s).

Exposed body area: The amount of Soldier body area exposed to possible enemy fire during the engagement. Bodily exposure area metrics were specifically calculated at the initial and final shot frames. Area (pixels^2) is calculated by summing the number of pixels containing exposed parts of the body and equipment on each frame. The area can also be converted to cm2 using a known distance within a single video frame, or estimated during visual observation based on vertical and horizontal measuring strips.

Cumulative exposure area: Bodily exposure can be calculated across the entire engagement, for every frame of the exposure in order to derive cumulative exposure area across those frames measured in both units of pixels^2*s and cm^2*s. Cumulative exposure area metrics are estimated using the trapezoidal rule (approximating the region under the curve with trapezoids) of the area curve over identical time intervals as the duration metrics.

4.3.2 Equipment Considerations

The equipment required to measure survivability is dependent on the resources available. At a minimum, measuring tapes on the obstacles for manual readings by the data collector are required. If available, the use of video cameras mounted behind firing positions is recommended in order to get a more accurate measure of the degree of exposure of the participant over time.

A data collector can collect survivability data utilizing manual methods in real-time. To measure exposure area, the researcher will take visual observations using two measuring strips in centimetres attached to the sides of the obstacles of interests as a reference, with lines at known increments of 5 centimeters, similar to a previously used training method [29]. A simple area calculation can be derived from the horizontal and vertical distances observed. A stopwatch or the internal clocks of the targets (if available) can be used to determine the duration of time for which the participant was exposed for each scenario.

Although manual estimation of the degree to which the participant is exposed while engaging targets can be adopted, we recommend using video cameras located five meters behind the firing point to capture this information. Using cameras will reduce the data collector workload and reduce the likelihood of lost data due to human error. Degree of exposure as extracted from video after the fact is also expected to be more accurate than estimates taken by the data collector in real time. Image processing techniques have been developed and prototyped utilizing commercial-off-the-shelf products (e.g., MATLAB) [29], [42]. This technique was not utilized in the SWEAT pilot testing due to limited resources available for data processing. However, it will be necessary to further develop this technique for use on live-fire ranges in future iterations of SWEAT.

4.4 Subjective Questionnaires

Test participants should be asked to provide information on their experiences and preferences during the trials. At a minimum, baseline demographic data should be provided prior to all testing, and post-run questionnaires should be completed after each trial as well as at the end of the entire experiment. The post-run questionnaires should be taken immediately after the last engagement, in order to minimize any memory loss or other biases that may be introduced. The post-experiment questionnaire could also be in the form of a focus group, with the purpose of comparing test conditions and providing additional insight about the experimental conditions that may impact the trial results. Although subjective in nature, questionnaires can provide great value to the research team regarding areas that may not be captured fully in the objective test measures, or things that the methodology may not be sensitive enough to identify. These insights are critical to document for design considerations and acquisition milestone reviews.

4.5 DataBase Management

For simplicity and maximum compatibility, flat file output in either text or csv formatting is recommended. As illustrated in the sample Data Collection Sheet, uploading into a spreadsheet application can yield minimum standards of data processing, analysis, and graphical output. For video and audio recording, standard outputs from commercial-off-the-shelf devices are highly compatible across platforms, and so are suggested. See Annex D for an example excel file for data processing and analyses based on the UK pilot.

4.6 Overall Assessment of Performance

Although lethality, mobility and survivability are assessed simultaneously by SWEAT, we do not recommend attempting to combine scores from each vector (i.e., lethality, mobility, survivability) to arrive at an overall run score. Rather, we recommend that performance for each condition be summarized for each performance vector with emphasis placed on how the conditions under test differed, ideally using inferential statistics to identify where differences are statistically reliable. Identifying that a hypothetical 'Condition A' resulted in 10% more target hits than hypothetical 'Condition B', while also resulting in runs being completed 15 seconds slower is a meaningful description of the outcome of a test that the consumer can then take and base decisions upon. However, it is unclear how one would go about combining these two results and the resulting aggregate score may become too abstract to be actionable by consumers.

5.0 PILOT LESSONS LEARNED

5.1 Pilot Testing in Canada

A pilot trial at CFB Borden, Canada was undertaken to test the feasibility of the SWEAT concept in October 2019. Specifically, the goal of the pilot was to setup an abridged version of the course (roughly the first third) to assess the degree of fatigue induced, the use of automated targets, the difficulty of acquiring and engaging targets, and to identify data collection challenges.

The level of fatigue induced by the course, as well as the types of obstacles and target engagements were deemed by military participants as representative of those faced during operations. Using automated targetry was practical, as it greatly simplified target presentation and data collection, although the properties of the target system being used will impact their effectiveness. Specifically, the high number of targets required to run the course was noted. In order to cut down on the logistics associated with SWEAT, it would be beneficial to be able to reuse targets at multiple firing points. Because the types of targets used during this pilot (LOMAH targets) had to be sighted onto the firing point from which they were to be engaged, engaging the same target from more than one firing point was not possible. If SWEAT users intend to reuse targets in this manner, they must use automated targets that do not have this limitation (e.g., Saab IMLF targets, which were used in the pilot in the UK do not have this limitation).

The need for a dedicated data collector (in addition to the range safety officer) and the use of video cameras to record the run were also seen as critical by group members. Attempting to double-hat the data collector with a range safety or target operator role would result in the individual becoming overloaded and would likely result in errors. As such, it is recommended that a dedicated data collector run the course alongside the participant running the course. The use of walkie-talkies or other short-range, portable communication systems also facilitated communication among the data collection team (e.g., data collector, target operator, trial coordinator).

Differences in range safety best practices across the nations represented were also noted. As range safety regulations trump the task protocol, deviations from the SWEAT protocol must be accommodated to ensure that range safety regulations are being adhered to.

5.2 Pilot Testing in United Kingdom

The aim of the UK pilot trial was to verify that controlled Live-Fire Tactical Training (LFTT) is appropriate for assessing Soldier performance as a function of varying equipment, and that the data and metrics collected throughout the SWEAT course are sufficient to measure differences in SCEE.

In this pilot study, two treatments were assessed: one Soldier at a time ran through the course once (on day one) using the UK Individual Weapon (IW) SA80 L85 A3 variant, zeroed to the Elcan Specter OS4 x4 lightweight day sight (LDS), and again (on day two) with the SA80 L85 A2 variant with the same LDS. Due to equipment availability this factor (weapon system order) could not be counterbalanced across participants. However, given that the primary goal of the pilot test was to examine the feasibility of the SWEAT course, this shortcoming did not have an impact on the outcomes of the pilot.

Due to the similarity in configurations, and all A3 variants ran on the first day and all of the A2 variants ran on the second day, the differences shown are more indicative of a learning effect than participants' lethality and mobility being affected by the change in weapon configuration. The analysis on lethal effect proved to be successful, with the framework developed to allow effective data analysis on any differences across the two treatments tested. A variety of metrics (including hit percentages, shot group size and time to engage) could be drawn and illustrated effectively. The analysis on mobility also proved successful, with the framework for data collection allowing effective data analysis across the two treatments tested. Some significant lessons learned include:

- Training and instruction time was significant and required throughout the course. One or more practice dry runs (i.e., without target presentation or target engagement) are recommended to familiarize participants with the flow of the course and the firing postures they are to take at each firing point;
- Time stamps across collection technology is required for data synchronization in post processing;
- The lethality data should include a tag that describes the firing position adopted and what obstacle was used as cover;
- Range environmental factors should be considered (i.e., height of grass and terrain may affect mobility and sighting); and
- The sturdiness of the obstacles that need to be traversed needs to be confirmed to ensure that participants can move through/over them without damaging the obstacles or injuring themselves.

A full list of lessons learned can be found in the UK pilot test report in Annex F.

6.0 RECOMMENDATIONS

6.1 NATO Standard Recommendations

The research task group has reviewed primary documentation and literature regarding test and evaluation of Soldier weapon systems and marksmanship assessment. The nations have agreed upon the need for the development of an integrated test methodology for understanding the impact of Soldier, weapon and equipment factors on Soldier combat effectiveness and efficiency. The SWEAT recommendations provide an initial blueprint for test and evaluation and are customizable for application based on organization/country assessment needs. The recommendations do not include a way to aggregate the individual performance domain scores but rather provide the ability to model interactions across the performance outputs and conduct trade-off analyses to inform system design. With a variety of perspectives and priorities driven by end-users and stakeholders, a standardized aggregated score would not be appropriate or acceptable.

It is recommended that the SWEAT course be outlined in an official STANREC for distribution and use across the NATO test and evaluation communities. The STANREC should be reviewed periodically by a team of experts to determine whether a follow-on research task group is required for additional development and testing. It is also recommended that scientific validation of the tool be performed to ensure it is sensitive to changes in equipment configurations at the level required (either within a future NATO activity or elsewhere).

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Annex A – PROGRAMME OF WORK (PoW)

The Programme of Work should define how a Technical Team will carry out the activity identified in the TAP.

[1] Activity: SWEAT	
[2]Chair/Co-Chair: Brown, Stephanie (USA) Co-Chair: Tombu, Mike (CAN) Panel Mentor:	[3]Updated: 15/02/2022

[4]MAJOR ITEMS OF WORK / TIME SCALE:		
#	Description	Period
1	Gap Analysis and literature review	1Q
2	Analysis of alternatives • Literature review • Experimental phase • Risk and issue management process	3Q
3	Scenario development • Literature review • Experimental phase • Real soldier experience	3Q
4	Validation and verification	3Q
5	Draft report and recommendation for additional options	3Q
6	Final report	3Q

[6]MAJOR ITEMS OF WORK SCHEDULE		
#	Description	Date
A	Literature review findings	15 Jan 2019
B	Recommended course of action	15 Oct 2019
C	SWEAT concept (delayed by 12 months by COVID-19, delay reflected in Date column)	15 Jun 2021
D	Testing complete (delayed by 24 months by COVID-19, delay reflected in Date column)	01 Jun 2022
E	Draft report (delayed by 12 months by COVID-19, delay reflected in Date column)	30 Jun 2022
F	Final report (delayed by 12 months by COVID-19, delay reflected in Date column)	01 Oct 2022

[6]MAJOR ITEMS OF WORK SCHEDULE												
Action #	2018	2019				2021				2022		
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
1	A											
2				B								
3							C					
4												D
5												E
6												F

Remark: Below is a generic list of items that could be included in the schedule. It should be modified as necessary.

NB that 2020 has been excluded from the time line due to the COVID-19 Pandemic, which has caused a pause in activity.

Schedule of the activities (Start = Start of SAS-145 Task Group)

Start + 3 months	**A** Literature review findings
Start + 12 months	**B** Recommended course of action
Start + 33 months	**C** SWEAT concept (additional 12 months due to COVID-19)
Start + 42 months	**D** Testing complete (additional 12 months due to COVID-19)
Start + 45 months	**E** Draft report (additional 12 months due to COVID-19)
Start + 48 months	**F** Final report (additional 12 months due to COVID-19)

[7]PARTICIPATING NATIONS/ORGANIZATIONS:				
Belgium	Canada	Germany	Netherlands	Sweden
USA	Great Britain			

[8]CONTRIBUTIONS:	
#	Description
1	Gap analysis and background review
2	Primary integrated measures identification for human systems integration test and evaluation
3	Report with recommendations that outline primary course of action and integrated methodology

[9]HARDWARE/SOFTWARE:	
#	Description
1	Recommendations on equipment associated with live fire (i.e. targets, range dimensions, etc.)
2	LEAP obstacles plus additional combat obstacles and firing points
3	Software/code for automated processing application

[10]STATUS:
Working Phase – identifying course elements and testing recommended courses of action

[11]Technical Team Membership					
NMR	Full Name	Nation/NATO Body	Organisation Type	Email	Role
1					
2					
3					

KEYS TO THE SAS TECHNICAL TEAM SEMI-ANNUAL REPORT

1	Activity Reference Number, Type, and Title: SAS-###-RTG. For Exploratory Teams, the Activity Reference Number is: SAS-###-ET. The type of activity is noted by the letters after ###. Activity types are: Exploratory Team (ET), Long-Term Scientific Study (LTSS), Military Application Study (MAS), STO Lecture Series (RLS), STO Specialists' Meeting (RSM), STO Symposium (RSY), STO Technical Course (RTC), STO Task Group (RTG), Specialist Team (ST) and STO Workshop (WS). The Activity members will determine the Subject title of the proposal.
2	Activity Chair: Name, Nation. Panel Mentor: Name, Nation of SAS Panel point of contact for the activity content and/or sponsoring the activity chair.
3	Updated: Month/Year of this updated submission.
4	A description of each major item of work and a time scale required to meet the objectives given under the TAP (drafted before STB approval and at the latest completed during the planning phase).
5	A listing of significant milestones with dates occurring throughout the programme that could be used by the Panel/Group and the STB to monitor progress (drafted before STB approval and at the latest completed during the planning phase).
6	The chart is divided into quarters of the year. Ex: The first three calendar months (January, February and March) of 2017 are shown as 2017-A. Y1-B indicates Year One of the activity and could be replaced by 2017-B.
7	Updated list of the nations and sponsors/customers which have agreed to participate (filled in at the latest during the planning phase).
8	Confirmed contributions in terms of manpower, data, models, test beds, targets, equipment, computer time, etc. (filled in at the latest during the planning phase). Note: The nations are invited here to agree a "minimum effort" to be devoted to the common work. The "minimum effort" concept refers to that part of the national effort relating to the nation's direct contributions to the common work. It is thus a measure of the involvement of the nations in the area covered by the Technical Team. Members not providing that "minimum effort" will be invited to leave the Technical Team.
9	Agreement on hardware and software to be used for editing of reports from the team (including disk formats, word processor packages and solutions to overcome problems from use of different material and software formats and versions) (filled in at the latest during the planning phase).
10	A statement with sufficient justification if the Technical Team requests to close its activity as a Limited Participation Technical Team (see STO Collaborative Network Operating Procedures maintained by the CSO) (filled in at the latest during the planning phase).
11	The names and contact information (phone, fax, email address and mailing address) of the Technical Team Leader and participants (filled in at the latest during the planning phase).

Annex B – EXAMPLE TEST PLAN

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Trials Plan for Soldier Weapon and Equipment Assessment Tool (SWEAT)

Guidance

Section 1: General Overview

Overview				
Division: **PLS**		**Group:** **Land Environment**		
Trial Title: **Soldier Weapon and Equipment Assessment Tool (SWEAT) Trial Plan**				
Trial Type: **WOME - Weapon Assessment / Firing**				
Trial maximum security classification and special handling markings **OFFICIAL**				
Classification: **OFFICIAL**	**STRAP Level:** **None**	**Codeword:** **No**	**SAP:** **No**	**ACTO:** **N/A**
Start Date: **16/05/2022**		**End Date:** **19/05/2022**		
Project funding the Trial: **Project/ICAS Number: 710062** **Activity Code: 3004**		**DIIS – Reference Number:** **DSTL/DOC121628**		
Trials Plan Reference Number: **DSTL/DOC121628**		**Trials Plan Version Number:** **1.0**		

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Trials Plan Security Instruction: **No**	**Security Instruction Reference Number:** **N/A**

Summary of Trial Objectives and Scope

This trial will form part of the evaluation process for the Soldier Weapon and Equipment Assessment Tool (SWEAT), developed under NATO SAS-145.

The aim is to verify that controlled Live fire Tactical Training (LFTT) is appropriate for assessing soldier performance as a function of varying equipment, and that the data and metrics collected throughout the course are sufficient to measure this difference in lethal effect.

The trial will involve soldiers conducting individual fire and movement, firing on pop up targets at specified firing points. They will conduct this using their x4 optical scope and with iron sights. A data collector will follow at a safe distance behind the line of fire under the control of the Range Conducting Officer (RCO), who will time the participants' activity during the course.

The range will be ran by the RCO from the Infantry Trials and Development Unit (ITDU).

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Section 2: Index

Section 3: Creation, Review and Authorisation

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Author			
On behalf of Dstl, I have compiled this Trials Plan and can confirm that it complies with the requirements of all relevant Dstl Processes.			
Role: **Trials Manager**	**Name:** **Jon Russell**	**Signature:**	**Date:** **01/02/2022**

Trials Manager *(Appointed by Project Manager)*		
On behalf of Dstl, I can confirm that I am Suitably Qualified and Experienced to manage this trial and I will work to ensure this trial is managed and executed safely and securely, and in compliance with the requirements of all relevant Dstl Processes, current legislation.		
Name: **Jon Russell**	**Signature:**	**Date:** **01/02/2022**

Review			
On behalf of Dstl, I have reviewed this Trials Plan, associated Risk Assessment(s) and other documentation and believe all risks have been reduced to as low as reasonably practicable; and conducting the trial represents best value and use of resources for Defence and Security. I have checked to ensure the trial has been entered into the Dstl Trials Calendar and am content for this Trials Plan to proceed to the authorisation stage.			
Role:	**Print Name:**	**Signature:**	**Date:**
Technical Review (Mandatory)	Max Lowe	M Lowe	08/03/2022
Project Manager (Mandatory)	Nick Tolley	N Tolley	08/03/2022

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Review			
SHEF	Malcom Smith	M A Smith	08/03/2022
	.		
	.		

Authorisation			
On behalf of Dstl, I confirm that the trial has been entered into the Dstl Trials Calendar and I authorise the activities covered by this Trials Plan to proceed. I am confident that those named in Section 7 are competent and that the risks of the work are controlled to as low as reasonably practicable. I agree that the proposed Trials Manager and any Deputies are Suitably Qualified and Experienced for their duties and I approve their appointment. This document in conjunction with the risk assessment and other supporting information provides a Secure, Suitable and Sufficient Safe System of work for all participants. I accept the residual risk on behalf of the organisation.			
Role: **Group Leader**	**Name:** **Ann Richardson**	**Signature:** 	**Date:** **14/03/2022**

Section 4: Document Control

Date:	Version:	Reason for Revision:
16/08/2021	0.1	Initial draft
16/08/2021	0.2	TM draft
16/08/2021	0.3	New TP template used

17/08/2021	0.4	PM and Andy Rawson review
10/02/2022	0.5	Version to LTR
08/03/2022	**1.0 FINAL RECORD**	**Final & archived version**

Section 5: Risk Assessments and Associated Documentation

Type:	Document Reference Number:	Version:	Date:
Risk Assessment	DSTL/DOC121629	1.0	22/09/2021
Range Standing Orders	SPTA SO	1.0	01/09/2017
MODREC Protocol	2092/MODREC/21	1.4	08/03/2022
RASP	ITDU/STA/ISSSTA/CCD	1.0	29/03/2022

Section 6: Required Permissions and Licenses

SUAS Process

Permissions and Licenses:	Type:	Document Reference Number:	Date acquired:
MoD Research and Ethics Committee (MODREC) Secretariat	**Ethical approval**	**2092/MODREC/21**	**08/03/2022**

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Section 7: Key Roles and Responsibilities

Guidance: Where No additional responsibilities are required in the table below, please denote as N/A.

Name:	Role:	List additional responsibilities not included in extant role profile:
Jon Russell	Trial Manager	
Abi Roberts	Trials Support	
WO1 Joe Dunn	Military Advisor	
Martyn Law	Trials Support	
Arnie Delstanche	Trials Support	
Tom Young	Trials Support	
Nick Tolley	Trial Support	
Jack Briston	Trial Support	

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Section 8: Management of Change

All staff irrespective of role on a trial are authorised to stop any activity they consider to be unsafe, or that will have a detrimental environmental impact. Where staff are unsure about the safety of an activity it must not be undertaken until the TM has been consulted.

Where change/s to the trial have been identified always use the '**START**' principals of '**Stop, Think, Act, Review, and Tell'**. Work must be paused until the change/s have been discussed and suitable action agreed by the TM, (and Trials Conducting Officer, TCO, where applicable) and the trials team.

All changes that increase the residual safety risk or introduce a new unassessed safety risk must be recorded in the trials log and an amended trial plan and/or risk assessment submitted to the Authoriser (typically GL) for approval. The Authoriser may require the preparation of a new trials plan and risk assessment for approval before continuing with the trial. In all cases where a TM is unsure or in doubt about how to proceed, they must not undertake the related activity and refer to the Authoriser for guidance. **Authorisation must be received before work recommences**.

Where changes have been identified that will affect the security measures applied, specific Security Instructions, cost or trial technical outcomes they must also be communicated to the PM and any increase in residual risk must be recorded as above.

Once confirmation has been received, the TM (and/or TCO where appointed) will inform all staff involved in the trial of the change/s and how they are to be implemented. Work can then re-commence.

Scope of Change (1)	Changes to trials scope that may have a security, safety or environmental impact, where there is **NO** increase in residual risk, breach of existing control measurers or introduction of a new unassessed threat/hazard; where assessment and sign off falls within the existing skill set, experience and overall competence of the Trials Manager or TCO.
Process for Agreement	Discussion and agreement with trials team.
Authorisation	Trials Manager.

Scope of Change (2)	Changes to trials scope that may have a security, safety or environmental impact, where there is **NO** increase in residual risk, breach of existing control measurers or introduction of a new unassessed threat/hazard; that the Trials Manager or TCO have insufficient knowledge and experience to assess and sign off.
Process for Agreement	Discuss with technical staff on trial.
Authorisation	i. Where trials team have determined a way forward with no adverse environmental or safety impact the Trials Manager may authorise. ii. Where the trials team are not able to determine a way forward the activity must stop and the Trials Manager must contact the Authoriser who will engage suitable technical experts as necessary.
Scope of Change (3)	Changes to trials scope that may have a security, safety or environmental impact, where there is an increase in residual risk, breach of existing control measurers or introduction of a new unassessed threat/hazard; or where the Trials Manager or TCO has doubt regarding the ongoing efficiency of existing control measures or Emergency Arrangements.
Process for Agreement	Trials Manager to discuss context and changes with Authoriser.
Authorisation	Authoriser to review environmental/safety implications of the change and seek expert support where necessary. Where the Authoriser is content that risk following change is appropriately controlled and managed they must record this in the amendments section on the RA and can then authorise the trial to continue. Where they are not content risk is appropriately managed the change cannot occur or the trial must stop. **Note: If the trial is being conducted on a Dstl Range then the owning GL and RSO must be consulted throughout.**

Additional Requirements
N/A

A copy of this trials plan will be held by the TM during the trial, for the recording of minor changes that do not affect overall risk. All changes must also be recorded in the 'Trial Log' for future reference.

Section 9: Personal Protective Equipment

Foot Protection			
PPE TYPE	**Required?**	**Standard**	**Specification**
Safety Boots	**No**		
Safety Shoes	**No**		
Any additional details: Walking boots or equivalent to be worn.			

Hand Protection			
PPE TYPE	**Required?**	**Standard**	**Specification**
Hand Protection	**No**		
Any additional details: .			

Head Protection			
PPE TYPE	**Required?**	**Standard**	**Specification**
Head Protection	**Yes**		
Any additional requirements: **Helmets and body armour must be worn by anyone on the range, as per Pam 21. An area for clear of this restriction will positioned outside of the range area. This will be provided by ITDU prior to the trial.**			

Hearing Protection					
PPE TYPE Standard	**Required?**		**Specificatio**		
	Yes		**H**	**M**	**L**

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Hearing Protection		**EN352-1:2002 Ear muffs**	**28**	dB	**25**	dB	**16**	dB
Any additional details: **To be worn during live firing at the direction of the range conducting officer (RCO). Ideally active hearing defence is worn to facilitate communications between the trial team.**								

Vision Protection			
PPE TYPE	**Required?**	**Standard**	**Specification**
Safety Spectacles: for Low & Med impact protection against particles and objects.	**No**		For Artificial Optical Radiation (AOR) Consult the Laser Safety Advisor
Safety Goggle: for Low & Med impact protection against particles, objects, dusts liquids some vapours.	**No**		For Artificial Optical Radiation (AOR) Consult the Laser Safety Advisor
Face Visor for Med & High impact protection against particles, objects and liquid splashes.	**No**		

			For Artificial Optical Radiation (AOR) Consult the Laser Safety Advisor
Any additional details:			

Outerwear			
PPE TYPE	**Required?**	**Standard**	**Specification**
Hi-Viz Vest	**Yes**	EN471:2013 High Visibility Clothing	**Class 1**
	No	EN471:2013 High Visibility Clothing	
Outdoor Clothing including foul weather gear.	**Yes**		
Coveralls		Comments:	
Any additional details: **Walking boots or equivalent to be worn. Clothing suitable for May on a military range in the UK with a waterproof jacket and cold weather clothing to hand.**			

Additional Requirements
Please include any additional or supplementary information here (include reference to security measures applicable to PPE where it is being Trialled). **Helmets and body armour must be worn by anyone on the range, as per Pam 21. An area for clear of this restriction will positioned outside of the range area. This will be provided by ITDU prior to the trial.**

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Section 9b Respiratory Protective Equipment (RPE) *(Delete table if not required)*						
RPE Type	**Required**	**Manufacturer**	**Model**	**Filter**	**Power Pack**	**Additional Requirement**
N/A						'Fit Test' Required
N/A						

Section 10: Emergency Plan

- *Dstl First Aid policy:*

All trial participants must be familiar with the emergency response plan and the initial actions to take. A quick assessment of the scene may be required and an accurate situation report communicated to the Emergency Services (via 2222 if on a Dstl site, 999 if on an external site or in accordance with the Host site's requirements). For Overseas Trials, the TM should obtain the required details from the overseas site host for inclusion within the emergency response plan. UK/OS Participants should carry a copy of the Dstl Travel Contact Card.

This first report is vital and an ETHANE (Exact location, Type, Hazards, Access, Numbers, Emergency services) report enables key information to be delivered to the emergency services. An ETHANE reporting template can be found at Section 25: Annex A. Please print and retain in an easily accessible place.

Emergency Action Plan
Whilst on the designated training areas, minor injuries such as cuts or sprains will be dealt with by a MATT 3 qualified member of ITDU. Any injuries will be reported as soon as they occur and will come under the control of the military activity owner (ITDU). **In the case of a serious incident, the emergency telephone numbers will be used.**
Emergency First Aid Arrangements
In the event of an emergency resulting in Personal injury, first aid will be administered by the following: *(Add / remove rows as required)*

First Aid Cover:		
Specialist Medical Requirement:	**Ballistic Trauma**	
Cover provided by:	**Name of First Aider:**	**Qualification:**
MOD	**Sgt Sam Fisher**	**MATT 3**
Dstl	**WO1 Joe Dunn**	**MATT 3**
MOD	**Cpl Danny Bucket**	**Combat Medic Technician**

Type and location of first aid kits and defibrillators where available:	
Type:	Location:
Standard 1st Aid kit + Ballistic Trauma pack	**ITDU safety vehicle**

Local site emergency contact information		
Where a serious incident has occurred and/or additional emergency response is required contact the following:		
Name/Service:	**Telephone:**	**Location:**
Range Control	**01980 674706**	**Westdown Camp**

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	Call sign: **N/A**	
Fire	**999**	
Ambulance	**999**	.
Security	**999**	
Medical Centre/ Duty Doctor/Nurse	**01985 222648**	**Warminster Medical Centre**

Dstl/Project Emergency Contacts		
Name:	**Telephone:**	**Position:**
DSTL Duty Officer (DDO)	**+44(0)1980 955555 -Option 1**	**24hr DSTL Emergency contact when working in the UK or Abroad.** **Do not delete - required for all trials**
Kirsty Mills	**01980 956746** **kemills@dstl.gov.uk**	**Team Leader for Abi Roberts, Arnie Delstanche and Jack Briston**
Julie Slater	**01980 951277** **jeslater@dstl.gov.uk**	**Team Leader for Nick Tolley**
Byron Melly	**01980 956805** **bdmelly@dstl.gov.uk**	**Team Leader for Joe Dunn**
Stuart Bridewell	**01980 951344** **sbridewell@dstl.gov.uk**	**Team Leader for Jon Russell and Tom Young**
Dean McClenaghan	**01980 952837**	**Team Leader for Martyn Law**

External Emergency Response Note: on Dstl / MOD owned sites contact the Site Contol Room and the local responders will liaise with external agencies		
Where a serious incident has occurred and local arrangements are limited to first Aid only and an external emergency (999/911 etc.) response is required COMPLETE THE ATTACHED SHEET IN ANNEX A AND contact the following:		
Name/Service:	**Telephone:**	**Nearest Location to Trial:**
Range Control	**01980 674706**	**Westdown Camp**
		.
		.

Nearest Hospital with A&E facilities or Specialist Medical Centre			
Hospital, Medcentre	Address:	Tel:	Distance from Trials location:
Salisbury District Hospital	**Odstock Rd, Salisbury** **SP2 8BJ**	**01722 336262**	**16.4 miles**
		.	.
		.	.

Additional information not detailed above

SPTA Range Standing Orders **page 3 – 5.**

To assist in the management of an emergency a report template has been provided in Appendix A. It is strongly recommended that Trials Managers complete any details that can be filled in prior to the trial commencing and that copies of the form are made available at all trials locations.

Section 11: Incident Reporting

In the event of a serious incident occurring on a Dstl trial site the details must be reported to the Owning GL and the DDO or DEIM immediately.

Examples of a serious incident include, but are not limited to, incidents that:

- Have the potential to impact the health or life of participants
- Impact the health or life of participants (especially with regards to RIDDOR)
- Cause significant harm to the environment
- Affect Dstl's reputation or financial standing

All incidents including near-misses must be recorded in the trials log and reported in accordance with the Dstl incident reporting process. This process also requires the incident type to be identified. I.E. safety, security, environmental etc.

In the event of an incident, the line manager and HR are responsible for making arrangements to contact family members using the Kinforming process. When on non Dstl/MoD sites, f the same process is to be followed and additionally the host site must be informed; the host site will be responsible for any internal reporting requirements in accordance with their procedures and incident management system.

Guidance: The above text represents the minimum expected standard for all Dstl trials. Where trials may have extra reporting requirements, for example a host site's incident reporting process this should be recorded here.

Additional Measures (if applicable)
N/A

Section 12: Environmental Protection Issues & Waste Management Plan

Environmental & Waste Management Details	
Guidance: The issues detailed below must be considered when planning and subsequently conducting a trial. Controls are to be put in place in accordance with MOD and Dstl Policy and Process. For help and advice please contact the following: RuralEstates@dstl.gov.uk envprotectionsustainability@dstl.gov.uk Are there specific Ecological, Environmental or sustainability requirements specified by the facility or land owner or determined by regulators Yes ☐ No ☒ If yes provide details:	
Does the location at which the trial is to take place have any or is next to any of the following conservation designations? Please check the box against any that apply:	
Site of Special Scientific Interest (SSSI) ☐ Special Protection Area (SPA) ☐ Special Area of Conservation (SAC) ☐ RAMSAR Wetland Site ☐ Marine Conservation Zone (MCZ) ☐	Scheduled monument, listed building or archaeological area ☐ Marine Protected Area (MPA) ☐ National Park ☐ Area of Outstanding Natural Beauty (AONB) ☐ National Nature Reserve (NNR) ☐ Local Nature Reserve (LNR) ☐ Local Wildlife Sites ☐
If you have checked any of the above designations, have you had pre-assessments conducted (where required) and obtained the required permissions and consents?	

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If you have answered yes to the above question, what controls have been put in place to mitigate any potentially negative impacts? *In relation to the above, when planning your Trial, you must allow sufficient time to obtain consents and permissions from the relevant authorities. For example: it can take a minimum of 16 weeks to gain consent to work at a location with protected characteristics, or considerably longer (over 6 months) if pre-trial assessments are needed.*

streams/rivers) or groundwater contained in below ground aquifers (permeable rocks/sands and gravel); either directly or through leaching? Yes ☐ No ☒ If yes provide details:
If the Trial is taking place in the marine environment, has a marine environmental impact assessment been conducted in accordance with legislative requirements and MOD Policy? Yes ☐ No ☐ N/A ☒ If 'no' or 'N/A' provide justification: *Further information, guidance and SME POC can be found at* http://wiki/o/Marine_Environmental_Protection
Have travel arrangements considered the environmental impacts (carbon emissions) associated with the chosen mode? Yes ☐ No ☒ N/A ☐ If yes, describe how you intend to mitigate such impacts. If No, provide a justification for not considering such impacts: **Vehicles needed for transportation of equipment.**

Will the Trial necessitate the hire of plant and equipment? Yes ☐ No ☒ If yes, have you considered the following: • Oil fuel or chemical spills Yes ☐ No ☐ N/A ☐ • Potential for fires Yes ☐ No ☐ N/A ☐ • Potential for disturbance/damage to flora, fauna or sea life Yes ☐ No ☐ N/A ☐ • Noise pollution negatively impacting nearest receptors Yes ☐ No ☐ N/A ☐ • Dust/smoke/fume generation affecting nearest receptors Yes ☐ No ☐ N/A ☐ • Potential for residues, debris etc. to be left behind e.g. contamination, pollutant Yes ☐ No ☐ N/A ☐ If you have answered yes to any of these, provide details of the proposed control measures bearing in mind the need to demonstrate that the Best Practical Environmental Option has been applied:
Will the Trial generate hazardous or sensitive waste? Yes ☐ No ☒ Will the Trial generate non-hazardous waste? Yes ☐ No ☒ If you have answered yes to either of these questions please briefly describe the nature of the waste that will be generated: If you have answered yes to either of these questions please briefly describe the security measures that will be applied to secure the waste until disposed of:

Has the waste producer (the person whose activities produced the waste) determined an appropriate disposal route for all wastes that will be generated? Yes ☒ No ☐ If yes, describe who will be managing the waste and how/where it will be disposed. If no, describe how the waste will be managed in accordance with national legislative requirements. **Waste (obstacles) will be returned to Dstl Porton Down for destruction.** *Guidance:* *A. Wastes must only be passed to an authorised person (Licenced waste carrier, broker or dealer) and hazardous or sensitive/controlled substance waste may require specific disposal routes to be agreed before the activity commences; this may include returning specific waste generated to Dstl for controlled disposal.* *B. It is the waste producer's (and others who take possession of the waste) legal duty to ensure that waste is managed in a facility that is permitted to accept such waste.*

Section 13: Dates/Working Hours

Start Date:	Expected End Date:	Duration (days):	Built-in Contingency (days):
16/05/2022	**19/05/2022**	**4**	**0**
Start time: **0830**	Finish time: **1700**	Working hours: **7.5**	

Dstl staff are bound by the Working Time Regulations. If you intend to exceed these limits, formal, voluntary opt-out must be obtained from all affected staff. Trials must be planned to take into account the entitlement of staff to take rest breaks and rest days. Trials staff can be asked to work through some rest periods, but they have the right to refuse to do so. Limits on the number of hours of night working (between midnight and 5 am) and use of young workers (under 18) must be adhered to. Time taken to travel from accommodation to the trials site must be included in the planned working time for the day.

Link to Working Time Regulations: http://www.legislation.gov.uk/uksi/1998/1833/regulation/2/made

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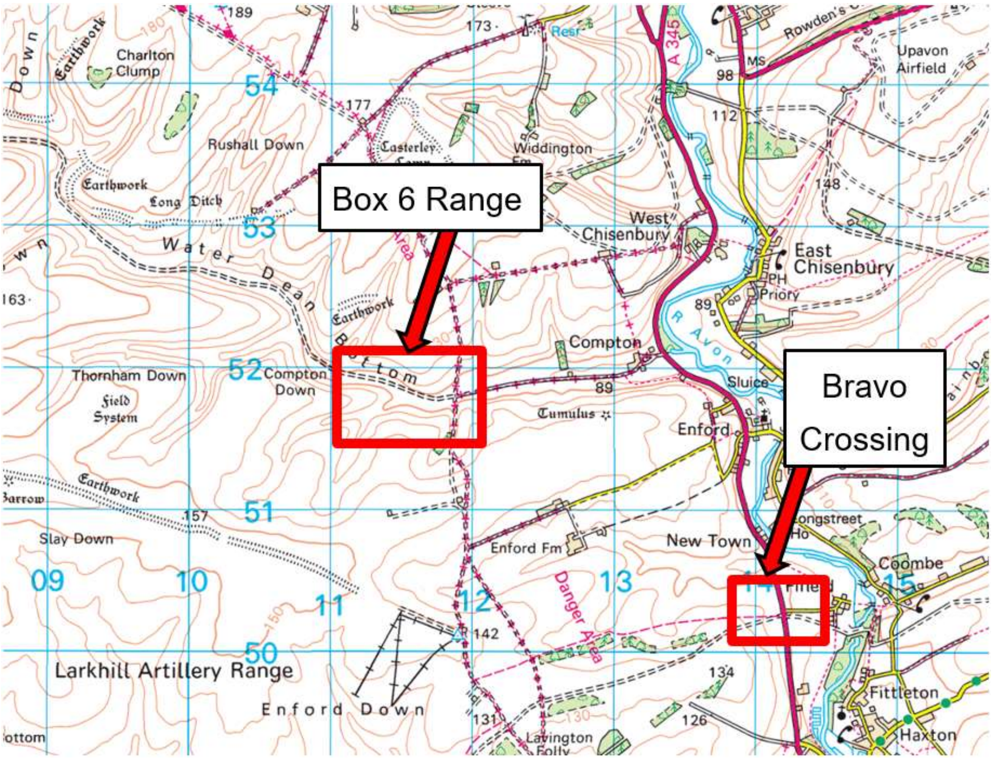
Section 14: Location

Site Details
Box 6 Range, **Enford,** **Wiltshire,** **SN9 6AS** **OS Grid SU 11 51** **What Three Words: stage.heaven.videos** **The range is situated on a flat grass field within a small valley on the West side of Salisbury Plain training area. Access is gained by a smooth, well maintained, gravel road via Salisbury Plain Bravo crossing.**



Section 15: Security Classification and Requirements

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Security Considerations and Trials Security Instruction (if applicable)
All electronic equipment and instrumentation will be removed from the trial site at the end of each day, and secured by ITDU. **Data will be recorded and stored on Dstl laptops and notebooks, all data will be classified OFFICIAL.**

Section 16: Administration & Staff Logistics (including Travel & Accommodation)

Add / delete rows as required.

Name	Team/Div.	Date of travel	Travel & Accommodation Arrangements
Jon Russell	Reactive and Passive Protection Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Abi Roberts	Close Combat Team/PSD	16/05/2022	Solstice Park, Holiday Inn
WO1 Joe Dunn	Mounted Systems Engineering Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Martin Law	Land Capability Analysis Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Tom Young	Reactive and Passive Protection Team/PSD	16/05/2022	Solstice Park, Holiday Inn

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Arnie Delstanche	Close Combat Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Nick Tolley	PM Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Jack Briston	Close Combat Team/PSD	16/05/2022	Solstice Park, Holiday Inn
Tilly Walters	Close Combat Team/PSD	16/05/22	Solstice Park, Holiday Inn

Section 17: Full Objective, Scope & Method

Trial Details
Objective: **The purpose is to conduct a live fire test over an obstacle course to determine whether there is a difference in marksmanship of trained soldiers based on the use of a x4 optical sight and the weapon iron sights.**
Scope: **The trial will inform the work of the NATO SAS-145 panel in creating a tool that will enable effective analysis of the performance of Soldier System lethality as a function of non-materiel and materiel combinations.** **Expected outcomes:** • **Produce evaluation of the use of controlled life fire tactical training (LFTT) training to assess weapon system performance** • **Produce analysis to confirm differences in weapon system performance**
Method: **The range furniture (targets and firing positions) will be transported to the range on the 16 May. ITDU have primacy on the range, all conduct on range including equipment will**

set up and control of the participants and Dstl data collector will be done under the direction of the ITDU Range Control Officer (RCO).

16/05/22 – Collect obstacles from PTN ISO park.

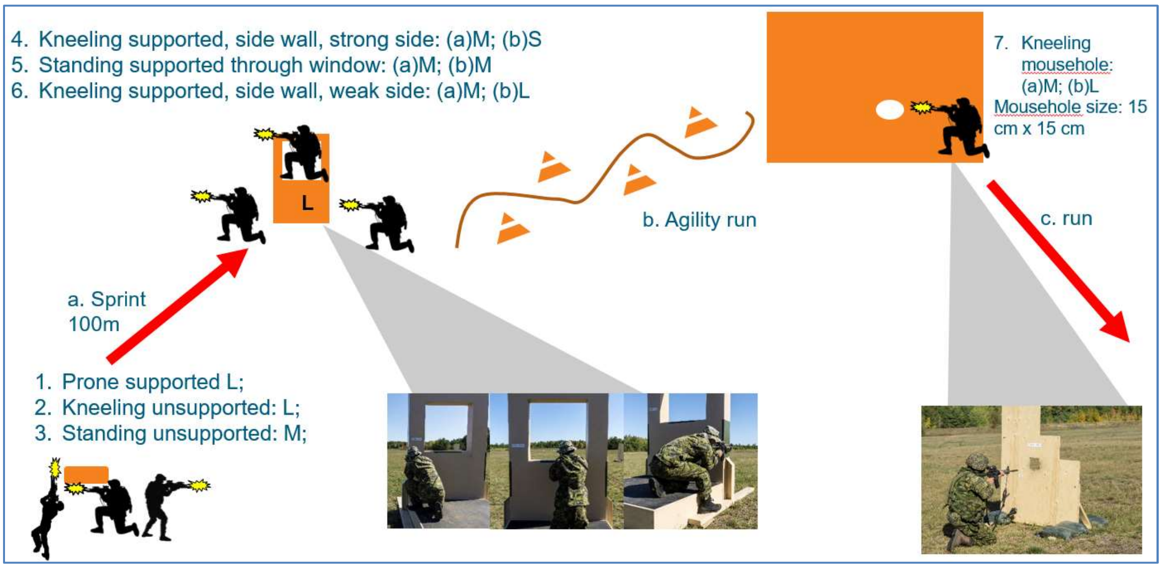
16/05/22 – Range set up (under ITDU) and weapon zeroing.

17/05/22 – Introduction to range and continuation of familiarisation shoots. Soldiers conduct first test runs of SWEAT course.

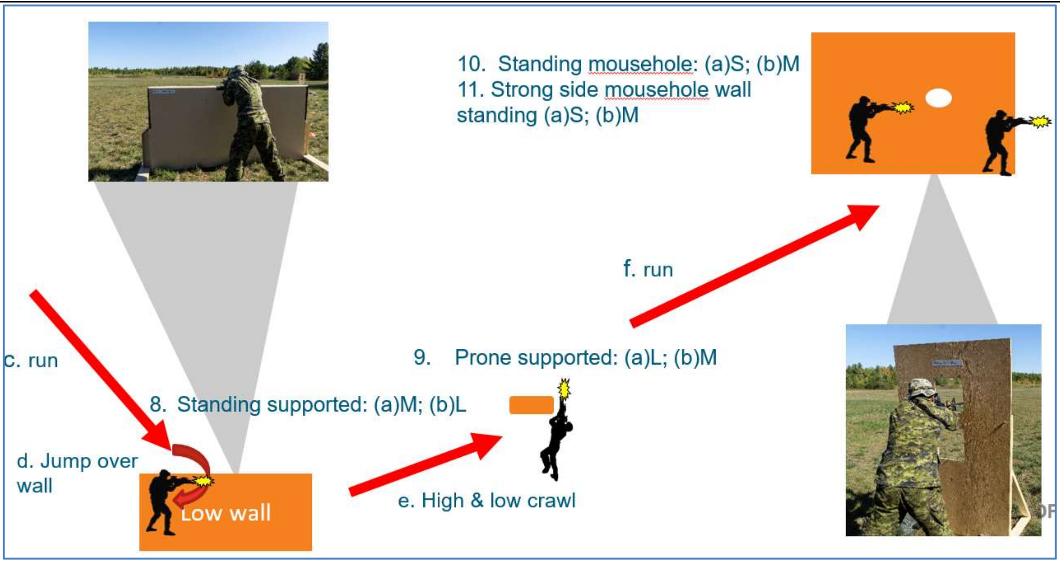
19/05/22 – Conclusion of test shoots. Range de-brief.

The course will be laid out as per the diagrams below

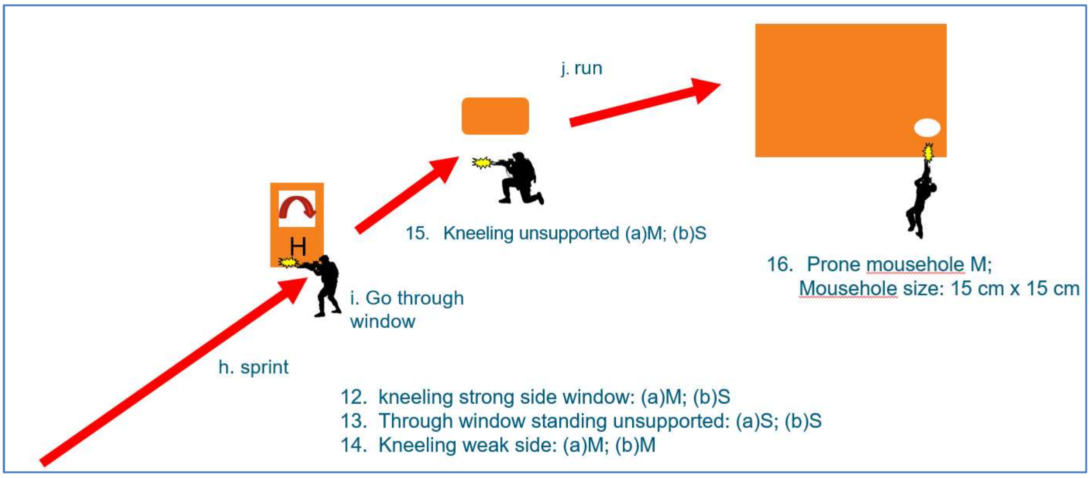
PART 1



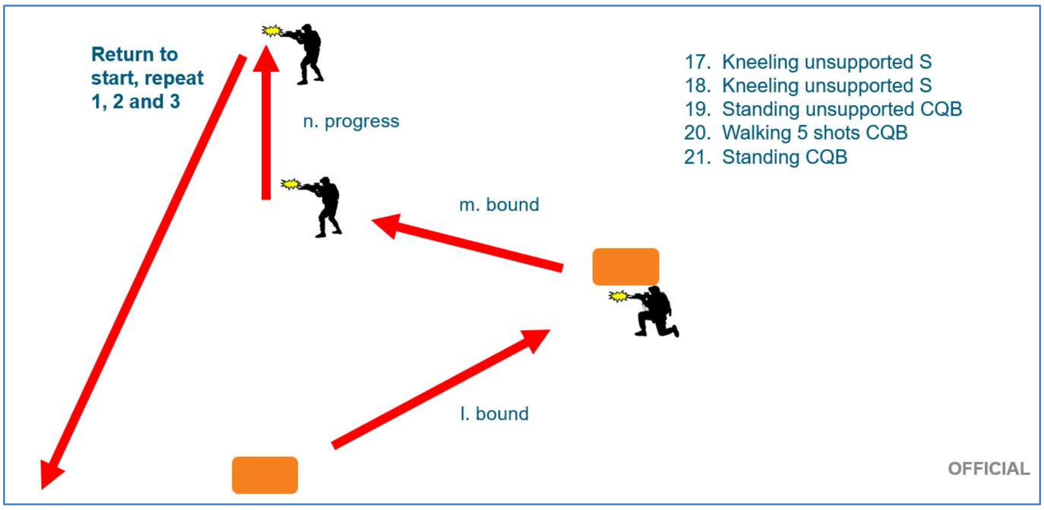
PART 2


10. Standing mousehole: (a)S; (b)M
11. Strong side mousehole wall standing (a)S; (b)M
f. run
c. run
9. Prone supported: (a)L; (b)M
8. Standing supported: (a)M; (b)L
d. Jump over wall
Low wall
e. High & low crawl

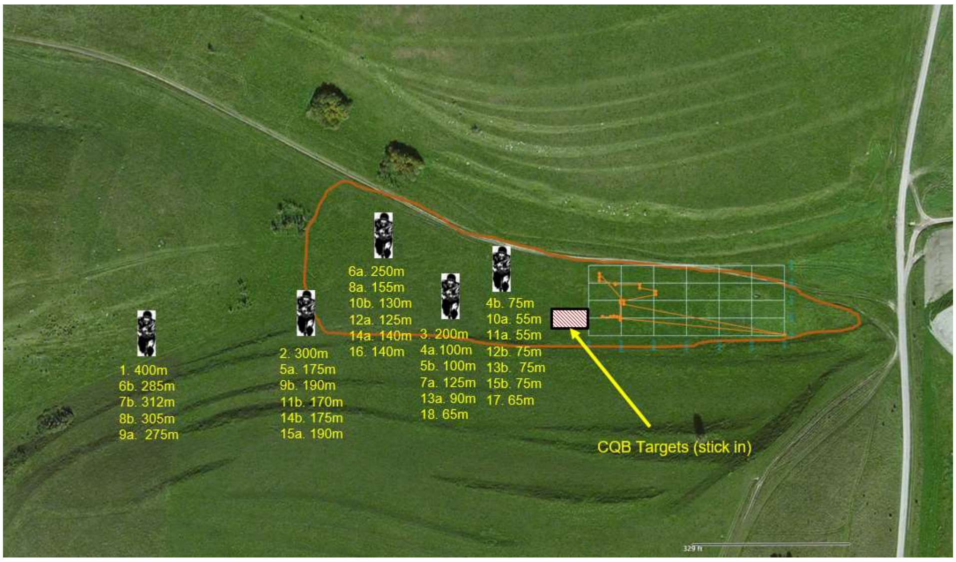
PART 3


j. run
H
15. Kneeling unsupported (a)M; (b)S
16. Prone mousehole M; Mousehole size: 15 cm x 15 cm
i. Go through window
h. sprint
12. kneeling strong side window: (a)M; (b)S
13. Through window standing unsupported: (a)S; (b)S
14. Kneeling weak side: (a)M; (b)M

PART 4



Five “pop up” type Figure 11 SARTS targets will be placed downrange from the course and laid out as shown below (distances are indicative and not exact).



Data collection and analysis:

A number of GoPro’s, and stopwatches will be used to time the soldiers through the course with a shot timer used to capture shot times, these two metrics, along with the shot location data from the targets and a post course questionnaire will be collated after each run. An example data collection sheet is supplied below.

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	Measures during course						
	Timestamp: (Start of obstacle)	Timestamp: (End of obstacle)	Timestamp: (Time of shots fired. BEWARE of sound and bullet travel time.)	(Time of first shot fired. BEWARE of bullet travel time.)	Time to when target falls/hit target	Location of shot at target (x-axis)	(Location of shot towards target on y-axis)
	Mobility		Lethality				
Method of capture ->	Stopwatch		Acoustic device	Target Data			
Obstacle (optionals in yellow)	Timestamp	Timestamp	Timestamp of each shot fired	Timestamp of time to Engage	Timestamp of each hit	X location of shot	Y location of shot
1. Prone Supported - L							
1. Prone Supported - mag change							
2. Kneeling unsupported - L							
2. Kneeling unsupported - mag change							
3. Standing unsupported - M							
3. Standing unsupported - M mag change							
a. Sprint 100m							
4. Kneeling supported, side wall strong side - M; S							
5. Standing supported through (high) window - M; M							
6. Kneeling supported, side wall, weak side - M; L							
6. Kneeling supported, side wall, weak side - mag change							
b. Agility Run							
7. Kneeling mousehole - M; L (15cm x 15cm)							
c. Run							
d. Jump over low wall							
8. Standing supported - M; L							
e. High & low crawl							
9. Prone supported - L; M							
f. Run							
g. High wall							
10. Standing mousehole - S; M (20cm x 20xm)							
11. Strong side moushole wall standing - S; M							
h. Sprint							
12. Kneeling strong side window - M; S							
13. Stranding unsupported through window - S; S							
14. Kneeling weak side window - M; M							
i. Go through window							
15. Kneeling unsupported - M; S							
j. Run							
16. Prone mousehole - M (15cm x 15cm)							
16. Prone mousehole - mag change							
17. Kneeling unsupported - S							
k. Bound							
18. Kneeling unsupported - S							
l. Bound							
19. Standing unsupported - CQB							
m. Progress							
20. Walking unsupported - CQB (5 shots)							
21. Standing unsupported - CQB							
n. Return to start of course							
22. Prone Supported - L							
23. Kneeling unsupported - L							
24. Standing unsupported - M							

Course Conduct:

Prior to starting the course the participants will fill out a consent form and pre-trial questionnaire consisting of anonymised background information such as, age, rank, length of service, etc. All course participants will have the prerequisite standard of proficiency to conduct live fire ranges on an equivalent Individual Battle Skills Range (IBSR).

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During the course, the soldier will run through the course with the targets popping up to a set sequence. There will be four people on the range during the run: participant, range safety and a Dstl data collector timing the run with an additional safety supervising the data collector. The data collector will always be behind the line of fire at a safe distance under the supervision of a military member of staff they will use a stopwatch to record the soldier's progress through the course. The shot timer will be attached to the soldier and will be started before the commencement of each run.

After the soldier has completed the course they will carry out a full unload and return to a central admin point to complete a post course questionnaire. Whilst this is being done and the next participant is getting ready, the trials staff will enter in the stopwatch and shot timer data into the spreadsheet. Shot location data will be recorded by the target control system, if this is not possible a photograph of the readout will be taken and entered after the trial.

Up to 8 participants will traverse the course, once with weapon optics, and once without. The following participant order (left to right) will be followed:

Sight	Participant Number															
Optic	1	2	3	4									5	6	7	8
Iron					5	6	7	8	1	2	3	4				
	Day 1								Day 2							

Visitors:

Visitors are listed in Section 22a.

COVID-19:

All staff will travel separately to the trial location and provide their own food. The outdoor location of the trial will enable all staff to remain socially distanced throughout. Hand sanitiser and anti-bacterial wipes will be provided to ensure the decontamination of any equipment that needs to be shared.

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Section 17a: Energetic Stores & Compatibility *(Delete table if not required)*					
Item	Description	NEC[a] (g)	Qty.	NEQ[b] (Kg)	HCC[C]
L15A2	**5.56 x 45 mm**	**1.545**	**1,100**	**1,699.5**	**1.4S**

Section 18: Cooperation with Other Organisations

.

Details of Co-Operation (if required)
ITDU will have primacy on the running of the live fire range, including safety and first aid/incident management.

Section 19: Communications and Reach Back During Trial Activities

Dstl Kinforming Process

Communications Plan
At all times, communication between persons who are not co-located will be by mobile phone, either voice or WhatsApp. Mobile numbers for Dstl personnel on the trial are given in Section 22. The point of contact for ITDU is Sgt Sam Fisher (Sam.Fisher186@mod.gov.uk, 01985 222196).

Section 20: Equipment, Storage & Transport

Equipment Details
ITDU/Trial Troops will bring • **Targets (SARTS (5) and Figure 11 (3))** • **Range radios**

- Weapon systems (SA-80) and ammunition (1,100 off L15A2)
- Personal PPE
- PPE for Dstl personnel

Dstl will bring

- At least 2 Dstl laptops for data collection
- Trial logbooks
- Kestrel portable weather station
- Trundle wheel
- Camera
- Shot timer
- Stopwatches
- Video recording devices

WO1 Joe Dunn has responsibility for the management and security of all Dstl trials equipment.

Section 21: Staff Fitness/Medical Cover/Occupational Health

Health Requirements
All Dstl staff will be confirmed fit by OH following a trials medical.

Section 22: Personnel involved in the Trial

Name	Organisation	Rank	Role	Contact Details	Date LM confirms fit for trial
Jon Russell	Dstl	Mr	TM	01980951404	07/09/2021

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Joe Dunn	Dstl	WO1	MA	01980957846	N/A
Abi Roberts	Dstl	Miss	Trial Support	01980957827	25/08/2021
Martyn Law	Dstl	Mr	Trial Support	01980954996	10/02/2022
Tom Young	Dstl	Mr	Trial Support	01980956227	07/09/2021
Arnie Delstanche	Dstl	Mr	Trial Support	01980955582	05/10/2021
Nick Tolley	Dstl	Mr	Trial Support	01980956379	06/10/2021
Sam Fisher	ITDU	Sgt	RCO	01985222196	N/A
Jack Briston	Dstl	Mr	Trial Support	01980955655	25/04/2022
Tilly Walters	Dstl	Miss	Trial Support	01980953420	27/04/2022
Danny Bucket	MOD	Cpl	Combat Medic Technician		N/A

Section 22a Planned Visitors					
Name	Rank	Organisation	Date of visit	Time of Visit	Host/Escort
Gareth Davies	Lt Col	TwX	18/05/2022	0900	Nick Tolley

Section 23: Additional Issues Not Covered by the Above

Guidance: Include any issues not covered by this document or any additional information pertinent to the Trial that the Trials Planner / Trials Team may wish to include.

Additional Requirements
N/A

Section 24: Appendices

Within the context of this document, an Appendix is considered to be a document in full or part, or a large section of information which is integral to the Trials Plan, thus assisting with the effective & safe conduct of the Trial.

All Appendices must have their Security Classification individually marked.

Section 25: Annexes

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Annex A Emergencies / Incidents - All Trial Sites - Initial Response

This first report is vital and the ETHANE report enables key information to be delivered to the emergency services:

Simply answer the questions in the boxes provided, and give information to your emergency contact/s, listed above.

Your name	.		
Grid Ref (if known)		Time incident commenced	

ETHANE		
E	**Exact Location of Incident**	
T	**Type of Incident**	
H	**Hazards Present**	
A	**Access Route**	.
N	**Number of Casualties**	
E	**Emergency Services Required**	

Annex B Response and Recovery Action Plan

Should the progress / continuation of a trial be affected following the occurrence of an emergency / incident, the TM should have contingency plans in place through the creation / activation of a Response and Recovery Action Plan.

The output from you trials specific risk assessment should inform the production of your Emergency Plan/Arrangements for the immediate incident response and the subsequent recovery action plan. The main hazards associated with the trials activity identified in the risk assessment must be used to formulate response/recovery plans in the unlikely event of their realisation.

The plan should cover the initial response and actions required by staff to all likely emergency scenarios, The response action plan should describe the contingency arrangements for recovery and any environmental clean-up that may also be required..

Response to an incident should be generally undertaken using the following methodologies:

Lockdown, Evacuation, a combination of both or application of a specific contingency plan with situational awareness for response and recovery created through the use of the 5xCs:

- Confirm (Identify what has/could happen and who/what may be harmed/damaged)
- Clear (Identify potential/actual safe areas and move non-essential staff back out of harm's way considering wind direction etc,)
- OR
  Contain (deploy staff, techniques and/or equipment to contain, mitigate consequences further contamination)
- Cordon (Identify safe areas and apply cordon)
- Communicate (who needs to know/what do they need to know, how can they be told)
- Control (Manage access and control scene)

Section 26: Trials Attendance Sheet

- I confirm that I have read and understand this Trials Plan and all associated Risk Assessments.
- I am aware that if I have any safety concerns during the Trial then I **must** stop the activity at the next safe point and bring those concerns to the attention of the Trials Manager and / or Trials Conducting Officer.
- I confirm that I have read or been briefed on any / all Risk Assessments associated with this Trial.
- I understand the requirements and confirm that I will comply with the controls specified therein.

Organisation (Print / Capitals)	**Role/Purpose** (Print / Capitals)	**Name** (Print / Capitals)	**Signature**	**Date**

Organisation (Print / Capitals)	**Role/Purpose** (Print / Capitals)	**Name** (Print / Capitals)	**Signature**	**Date**

Annex C – LAYOUT PLANNING TOOL

Annex C is an Excel Workbook available on request from NATO STO Publications.

Annex D – DATABASE AND ANALYSIS PLANNING

Annex D is an Excel Workbook available on request from NATO STO Publications.

Annex E – TIMING APPLICATION TOOL

An Android-based SWEAT timing app was developed to capture critical mobility timing associated with SWEAT. The app keeps a searchable log of all data collected (see Figure E-1). Data logs can be browsed by clicking on them, as well as export in.csv format for analysis.

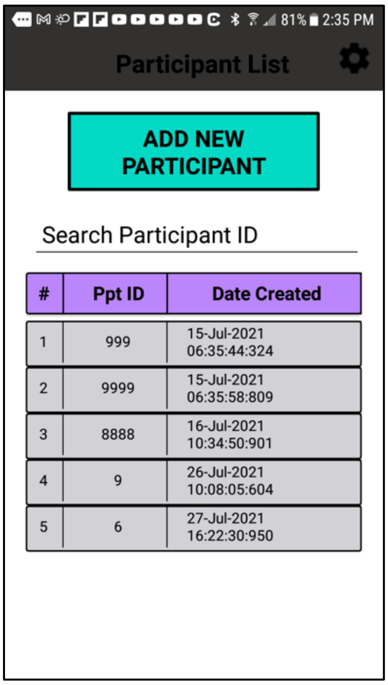

Figure E-1: SWEAT Timing App Home Screen Showing Searchable Data Log and Button to Log a New Participant Run.

To add a new run, the user simply taps the 'ADD NEW PARTICIPANT' button at the top of the screen, which brings up a data collection screen where the participant number can be inputted (See Figure E-2). To begin the run timing, the user taps the brown 'BEGIN TRIAL' button.

The 'BEGIN TRIAL' button then automatically updates to display the next timing gate (see Figure E-3). At any point the user can log additional time-stamped events related to participant falls (using the 'FALL' button), kit issues (using the 'KIT' button), shots (using the 'SHOT' button) and miscellaneous events (using the 'MISC' button), as well as move back/forward by a timing gate in case of user error.

The app can be used in real time while the participant runs the course, or as a post-run tool for extracting timing data from video-recorded runs. If used in real time, users are encouraged to ensure that data collectors are adequately trained on the use of the app to avoid data-collector overload. For more information on the SWEAT timing app please contact Mike Tombu (Mike.Tombu@forces.gc.ca).

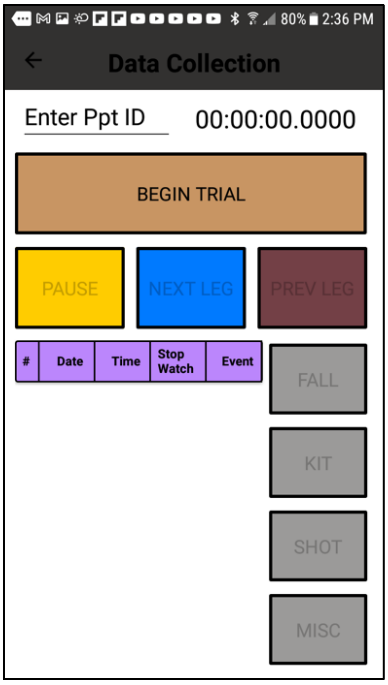

Figure E-2: New Run Start Screen. The user enters the participant ID (top left) and can begin the run by pressing the 'BEGIN TRIAL' button.

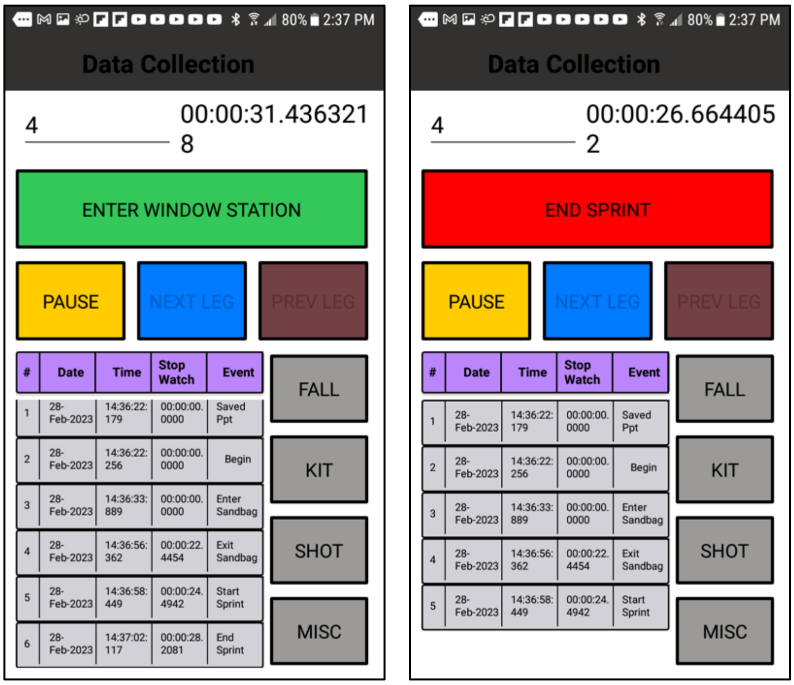

Figure E-3: SWEAT Timing App Features. The start button constantly updates to indicate the next timing gate that the participant will encounter. The left panel shows the display at the end of the sprint obstacles and the right panel shows the display at the beginning of the window station. Button color is used to indicate whether the next timing gate represents the beginning of a segment (green) or the end (red). In addition to logging segment start and end times, falls, kit issues, shot times and miscellaneous events can also be logged.

Annex F – UK PILOT TEST REPORT

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[dstl] The Science Inside

Soldier System Weapon and Equipment Assessment Tool (SWEAT) Pilot Trial

Russell, JD, Delstanche, A, Briston, J, Roberts, A, Walters, TE

DSTL/TR141291 v1.0
5 August 2022

Dstl
Platform Systems
Porton Down
Salisbury
Wilts
SP4 0JQ

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Authorisation		
Role	**Name**	**Signature**
Project Manager	Nick Tolley	05/08/2022 X [signature] Nick Tolley PM
Technical Reviewer	Noel Wilde	05/08/2022 X Noel Wilde Noel Wilde LTR
Author	Jon Russell	04/08/2022 X [signature] Jon Russell Author

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Executive summary

The UK pilot trial of the NATO Soldier System Weapon and Equipment Assessment Tool (SWEAT) was conducted to support the NATO Land Capability Group Dismounted Soldier Systems (LCGDSS) Weapon and Sensors (W&S) Team of Experts (ToE) panel to deliver the Systems Analysis and Studies (SAS) Panel 145 SWEAT. The NATO SAS-145 Panel will use the lessons learned from the UK pilot trial to develop a NATO Standardised Recommendation (STANREC) to inform partner nations of the SWEAT trial and data analysis method and how to develop and implement their own tool.

The aim of the pilot trial was to verify that controlled Live Fire Tactical Training (LFTT) is appropriate for assessing soldier performance as a function of varying equipment, and that the data and metrics collected throughout the SWEAT course are sufficient to measure this difference in lethal effect.

In this pilot study, two treatments were assessed: one soldier at a time ran through the course once (on day one) using the UK Individual Weapon (IW) SA80 L85 A3 variant, zero’d to the Elcan Specter OS4 x4 lightweight day sight (LDS), and again (on day two) with the SA80 L85 A2 variant with the same LDS.

Due to the similarity in configurations, and all A3 variants ran on the first day and all of the A2 variants ran on the second day, the differences shown are more indicative of a learning effect than participants’ lethality and mobility being affected by the change in weapon configuration;

It is concluded that:

Lethality

- The analysis on lethal effect proved to be successful, with the framework developed to allow effective data analysis on any differences across the two treatments tested;
- A variety of metrics (including hit percentages, shot group size and time to engage) could be drawn and illustrated effectively;
- Due to the similarity of both treatments, there was no significant difference between the lethality of the treatments, however the effect of range was evident;
- There was no significant fatigue factor in both accuracy and time to engage;
- With more participants, this analysis piece could be extended to assess changes in lethality across each individual firing point and firing position.

Mobility

- The analysis on mobility proved successful, with the framework for data collection allowing effective data analysis across the two treatments tested;

- Overall, for mobility, the results show there was a difference in total course completion time across treatments. However, there was no significant difference in the cumulative time in completing mobility obstacles;

- The course also has the potential to draw out the effect on mobility for specific obstacles of interest with a larger participant count.

Questionnaire

- The subjective feedback of the SA80 L85 A2 compared to the A3 variant provided a mixture of results between the two variants;

- The subjective feedback did not identify a clear preference between the two variants.

Following post trial data analysis, a number of recommendations relating to data analysis were identified:

- The risk of missing data points is mitigated by a robust and efficient data collection and data identification method, with any data gaps backfilled;

- Multiple instrumented recording devices (in this trial the Saab Small Arms Transmitter and the Saab Instrumented Targets) provide timestamps allowing data to be cross-validated;

- The lethality data should include a tag that describes the firing position adopted and what obstacle was used as cover;

- An additional Extra Long (XL) distance tag needs to be included to distinguish between at targets ~300m and ~400m away;

- Five shots on each of the first three firing serials (and their repeats at the end) is recommended with a low participant count (<10). With more participants, this could be reduced to three shots each;

- Future experimental design should consider mitigating learning effects of the participants;

- Use paired data when possible (fix each result to a participant), which requires having the participants running through all treatments of the course;

- The data extracted from this course will yield better insights if it is used as a comparative tool between treatments, rather than for standalone use;

- A data analysis dashboard is integrated into the course design;

- The course could be reduced in size (and time) if required, with negligible effects to the overall data analysis if the following changes to the course design were made:

    - Reduce the number of magazine changes from five to two (~1 minute);

- Remove firing point 8a (low wall, standing, medium range target) and 8b (low wall, standing, long range target) (~1 minute);
- Remove firing point 11a (mouse hole, standing, short range target) and 11b (mouse hole, standing, medium range target) (~1 minute);

- The quality of comparison between weak and strong-side firing would strongly benefit from having the same target distances for firing points 4a/4b (low window, kneeling supported, right-hand side) and their counterparts 6a/6b (low window, kneeling supported, left-hand side). Likewise for the distances of firing positions 12a/12b (low window, kneeling supported, right-hand side) and 14a/14b (low window, kneeling supported, left-hand side).
- An optimised schedule is proposed for firing points 4, 6, 12 and 14:
  - 4. Kneeling, RHS of window: (a) M (b) L;
  - 6. Kneeling, LHS of window: (a) L (b) M;
  - 12. Kneeling, RHS of window: (a) M (b) S;
  - 14. Kneeling, LHS of window: (a) S (b) M.

A number of recommendations were captured from the participants and the trial team. These were:

- Participant Recommendations:
  - Trial area needs to be on an even area with short grass;
  - VIRTUS magazine pouches are very tight and designed for the standard issue metal magazines. Magpul magazines proved to be a tight fit and added time during magazine changes. Magazines need to be compatible with the pouches being used;
  - Some targets were located in areas that required leaving cover to engage targets. Obstacles need to be designed/orientated to avoid the need to leave cover;
  - Firing on the weak side was unfamiliar and should be practiced.
- Course Organisers Recommendations:
  - Smart targetry is required to semi-autonomously track firers/firing;
  - Future experimental design should mitigate learning effects of the participants;
  - The Defence Research and Development Canada (DRDCs) timing app can be used post trial while reviewing the video footage;

- A semi-automated method of raising the targets in the correct order is required;
- Translating the layout (Table 1) to the real layout was difficult. This would benefit from a visual layout map with distances from both the start point and the preceding obstacle;
- Flat ground with short grass is required;
- The use of an LRF would be useful for confirming measurements and reduce error;
- Rationale is required as to what each firing point/position is representing;
- Large capacity memory cards in the GoPro's negates the need to transfer data after firing. 400 Gb memory cards were used and was able to capture footage of all serials;
- The low wall and low window obstacles need to be sturdier to allow participants to climb over/through them. The sturdiness of remaining obstacles was adequate.

Table of contents

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1 Introduction

This trial report was funded by the Dstl Land Systems Programme, Dismounted Soldier Systems Project, to record the UK pilot trial of the NATO Soldier System Weapon and Equipment Assessment Tool (SWEAT).

The trial was conducted to support the NATO Land Capability Group Dismounted Soldier Systems (LCGDSS) Weapon and Sensors (W&S) Team of Experts (ToE) panel to deliver the Systems Analysis and Studies (SAS) Panel 145 SWEAT study.

It is envisioned that SWEAT will be used by NATO and the UK MOD to quantify soldiers' lethal effect as a function of varying capability and equipment, in support of future procurement projects.

1.1 Background

It is well understood how to test the performance of a rifle and ammunition in isolation, but not how to assess the performance of the Soldier in the loop as an element of the Soldier System and relate it back to operational effectiveness.

To optimise soldier lethality, it is important to use a systems approach; weapons, ammunition, optics/enablers, soldier equipment, training, and human factors should be designed and integrated as matched components. At present, there is a lack of measurable, effects-based standards for measures of effectiveness of the entire Soldier System and the resultant effect on lethality. This impacts the ability of NATO nations to precisely define small arm requirements and evaluate potential solutions in operationally relevant scenarios.

The NATO LCGDSS W&S ToE identified a requirement to develop an operationally relevant assessment method that enables effective analysis of the performance of Soldier System lethality as a function of non-materiel and materiel combinations. The objective of the NATO panel is to develop a NATO Standardised Recommendation (STANREC) to inform partner nations of the SWEAT method and how to develop and implement their own tool.

Once standardised, the method can be utilised across NATO nations and international partners to assist with requirements generation, testing, evaluation and assessment of training.

1.2 Aim

The aim of the pilot trial was to verify that controlled Live Fire Tactical Training (LFTT) is appropriate for assessing soldier performance as a function of varying equipment, and that the data and metrics collected throughout the SWEAT course are sufficient to measure this difference in a soldiers' lethal effect.

The NATO SAS-145 Panel will use the lessons learned from the UK pilot trial to inform and refine future iterations of the SWEAT course/method as a STANREC.

1.3 Objective

The objective was to identify whether a comparison can be made between two equipment treatments - in this pilot trial, the SA80 L85 A2 and A3 variants were compared. However, the aim of this pilot trial was agnostic to the outcome of these comparative treatments.

The pilot trial was primarily interested in the feasibility of collecting the data for two treatments from an LFTT environment, and analysing the outputs. Therefore, there was no requirement in this trial for the data to have a high statistical power, just that a complete and representative data set be generated; namely a complete run through of two soldier equipment configurations with a section (6-8 soldiers) of dismounted close combat soldiers.

Despite a low participant sample size in this trial, statistical methods have been used to provide indicative analysis and exploratory outcomes to help inform the NATO SAS-145 panels' trial methodology (Section 4).

1.4 NATO SAS-145

The NATO SAS-145 panel brings together researchers across disciplines to develop higher fidelity, operationally relevant assessment methodology and metrics. This enables effective analysis of the performance of Soldier System lethality as a function of non-materiel and materiel combinations. The SWEAT tool can be utilised across NATO nations and international partners to assist with requirement generation, testing, and assessment of training, in order to:

- Objectively measure and analyse the performance of the dismounted soldier together with their weapon, equipment, ammunition and training;
- Develop a standard, engagement course (live, virtual, etc.) layout in relevant operational settings – representing the most common current and future NATO Missions;
- Incorporate commercially available targets, data collection hardware, and software;
- Develop a tool that will assess universal performance, including:
    - Data generation for capability comparisons within and between NATO-nations;
    - Any Nations' soldier, role, weapon, optic, equipment and enablers, training, ammunition combination, in both day and night;
    - Performance as a function of time and range among others;
    - Cognitive and physical effects;
    - An expandable modular and configurable course;

- Realistic operational framework.

- Recommend a standardisation in the form of a STANREC by the NATO NAAG LCGDSS.

The SAS-145 panel aims to:

- Determine the process and equipment necessary to provide a repeatable, modular, configurable, scalable, role based measure of the impact of materiel and non-materiel changes on Soldier System lethality;
- Collect and analyse data and metrics, including:
    - Target:
        - Type of hit;
        - x, y shot location;
        - Shot timing;
        - Time to engage;
        - Probability of hit (PHit) [1] as per STANAG 4513 [2] and STANAG 4512 [3].
    - Range:
        - Wind profile downrange
        - Air temperature
        - Range location
        - Range weather conditions
    - Participant:
        - Height;
        - Weight;
        - Carried load;
        - Time to complete run;
        - Training level;
        - Heart rate;
        - Demographics;

- Body temperature;
- Body position;
- Body exposure;
- Weapon orientation;
- Weapon and equipment configuration.

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2 Pilot Trial

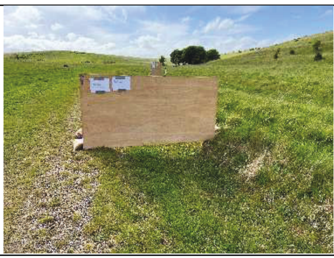
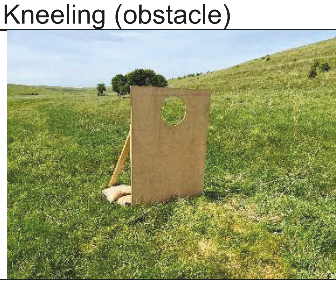
2.1 Location

The pilot trial was conducted 16-18 May 2022 on Salisbury Plain Training Area (SPTA), Box 6 (OS Grid: SU 11 51) (Figure 1). 16 May was used as an equipment set-up day.

Figure 1 - SPTA Box 6 location and view of the obstacle/firing area

2.2 Firing Points and Obstacles

The SWEAT course takes the form of a series of 14 firing points, 5 physical obstacles and 36 individual live fire shoots (serials) on a live range where soldiers have to move between firing points and various firing positions (standing, kneeling and prone) whilst engaging pop-up targets at each serial. All firing points and obstacles are presented in Figure 2.

		
Firing Point 1: Sandbag	Firing Point 2: Low Window (obstacle)	Firing Point 3: Mouse Hole Kneeling (obstacle)
		
Firing Point 4: Low Wall (obstacle)	Firing Point 5: Sandbag	Firing Point 6: Mouse Hole Standing (obstacle)

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Firing Point 2: Low Window (obstacle)	Firing Point 7: Sandbag	Firing Point 8: Mouse Hole Prone (obstacle)
		
Firing Point 9: CQB Sandbag 1	Firing Point 10: CQB Sandbag 2	Firing Point 11: CQB Sandbag 3
		
Firing Point 12: Move and Fire CQB	Firing Point 13: Sandbag	

Figure 2 - Images of SWEAT firing points

Dimensions of the obstacles are provided in APPENDIX A.

An illustration of the layout of the five obstacles (firing points 2, 3, 4, 6 and 8) are provided in Figure 3. The sequence and serial at all firing points is provided in APPENDIX B.

Measurements recorded firing accuracy and time to complete the course are presented in APPENDIX C and analysed in Section 4.

All obstacles were made of wood and nails were covered to help reduce the risk of bullet ricochet. Some obstacles (low wall and low window) were not sufficiently sturdy to allow the participant to go over/through. Therefore, participants were instructed to go around the obstacle instead. It is recommended that future versions of the course should be suitably durable to permit this activity.

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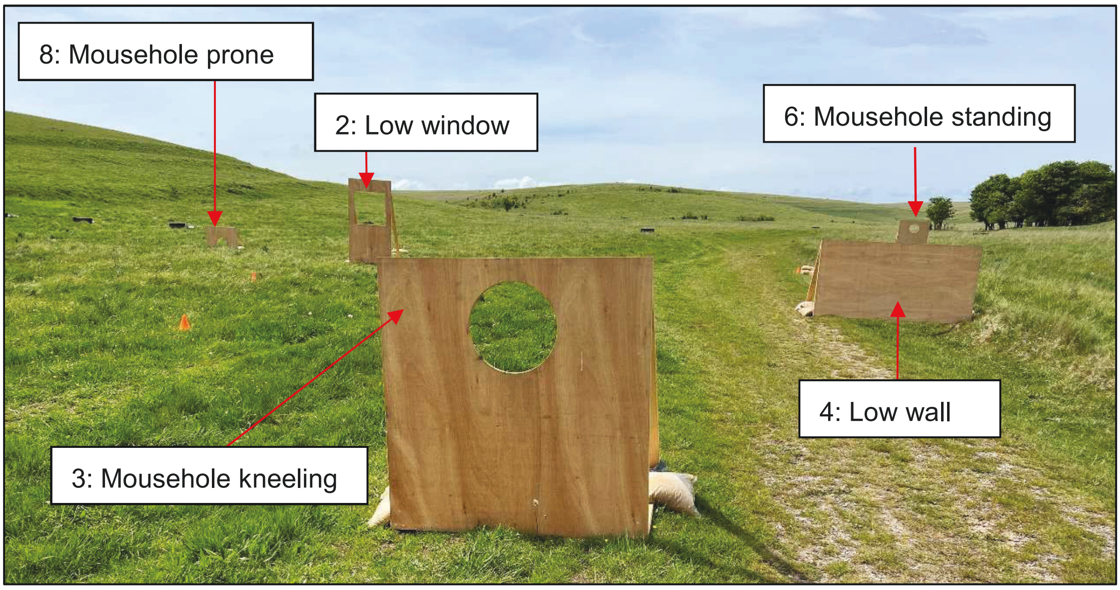

Figure 3 - Layout of 5 obstacles

A schematic of the course layout is provided in Figure 17.

2.3 Treatments

In this pilot study, one soldier at a time ran through the course once (on day one) using the UK Individual Weapon (IW) SA80 L85 A3 variant with the Elcan Specter OS4 x4 lightweight day sight (LDS), and again (on day two) with the SA80 L85 A2 variant with the same LDS.

The original plan was to compare performance of the SA80 L85 A3 with the LDS against the SA80 L85 A3 with iron sights. However, it wasn't until the trial commenced that it was identified iron sights were not compatible with the A3 variant. Therefore, the treatments were modified to compare the performance of the A2 and A3 variants with the LDS.

The two IW variants are extremely similar, and it was hypothesised that there would be little subjective and objective difference between the two.

Each SA80 L85 variant was zero'd prior to the trial in accordance with the Operational Shooting Policy (OSP) [4].

A visual comparison of the SA80 L85 A2 and A3 variants is presented in Figure 4. The SA80 L85s in Figure 4 have a Saab Small Arms Transmitter (SAT) sensor on the muzzle as part of the instrumentation suite for the targetry system.

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Figure 4 - Comparison of SA80 L85 A2 (left) and A3 (right)

The SA80 L85 A3 was assessed on day 1, and the SA80 L85 A2 assessed on day 2. For the purpose of the pilot trial, effects of learning the course were not considered, but a trial design to mitigate learning is recommended for future iterations of the course. Participants walked through the course with the trial staff to familiarise themselves with the layout, target locations and firing points and firing positions.

The changes from the SA80 L85 A2 to the A3 variant are [5]:

- The A3 is ~0.1 kg lighter than the A2;
- The A3 is coated in Cerakote® which has a high resistance to abrasion and weathering and a reduced visual and Infra-Red (IR) signature;
- The Trigger Mechanism Housing (TMH) is painted in “Flat Dark Earth” colour;
- A stud has been welded onto the TMH above the change lever to stop accidental over rotation;
- Auto replacement parts and refurbishment of all internal components;
- The Upper Receiver Body features enhanced welding for increased durability;
- A new A3 Combination Tool with a T15 Torx Tool;
- The dovetailed gas block has been machined allowing for a free floating handguard, which improves accuracy and consistency;
- A new anodised aluminium handguard supports the in-line Picatinny rail on the upper receiver, enabling the fitting of inline night optics in front of the day sight. The “Keymod” system reduces the width of the handguard and provides flexibility to attach ancillaries;
- New Picatinny mounted flip up Iron Sights - front and rear[1];

[1] The SA80 L85 A3 variants used on the trial did not have these fitted.

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- Detachable short Picatinny rail and Sling Loop;
- Enlarged hole for standalone Underslung Grenade Launcher (UGL).

2.4 Firing Points

At each firing point, participants were required to adopt various firing positions, illustrated in Figure 5. A full list of serials, including firing point, firing positions and target combinations are provided in APPENDIX B.

Standing

Kneeling

Prone

Figure 5 - Illustration of standing, kneeling and prone firing positions adopted at each firing point

2.5 Instrumentation

Two main forms of instrumentation for data collection and analysis were utilised:

- Targetry - Smart targets permitted the recording of impact location, timing from target exposure to first hit and subsequent hits;
- Participant timing – Video footage provided timing movement between obstacles and actions at each firing point.

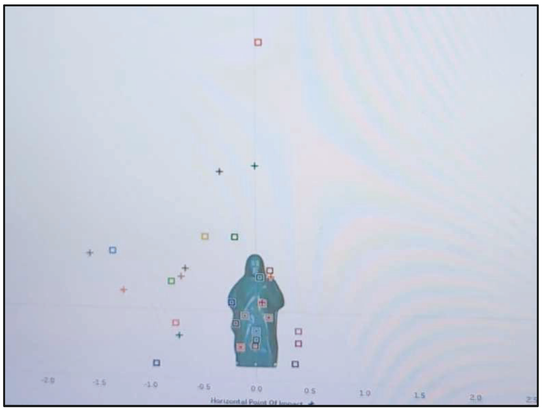
2.5.1 Targetry

To assess firing timing and accuracy, eight Saab Instrumented Metricised Live Fire (IMLF) targets were used to capture the x, y impact co-ordinates, time to hit (when target exposed), inter-shot timing and reaction time of each participant. This data is analysed in Section 4 and raw data presented in APPENDIX C.

The IMLF system is illustrated in Figure 6.

Target system mounted on lifting mechanism and Location of Miss and Hit (LOMAH) bar

LOMAH bar and lifting mechanism



Shooting accuracy software

Figure 6 - Saab IMLF system

The IMLF targets were set ‘bob’ (fall and raise when hit). Their order of exposure was dictated via radio to the target controllers who following the script in APPENDIX B.

More information on the Saab IMLF system is provided in Section 2.9.

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2.5.2 Timing

The timing of each participants' actions (reload, movement between obstacles, time to engage the target and exposure) was recorded using eight Go Pro's[2] situated throughout the course at the following locations:

- Cameras 1-5 spaced 5 m (±0.05 m) from the rear of each obstacle;
- Camera 7 mounted in an 'overview' position;
- Camera 6 mounted to the instructors' helmet;
- Camera 8 mounted to the participants' helmet.

The location of obstacles and camera are presented in Figure 7 and a course schematic presented in Figure 17.

Video footage was reviewed and the timing data noted. The data is presented in APPENDIX C and analysis presented in Section 5.2.

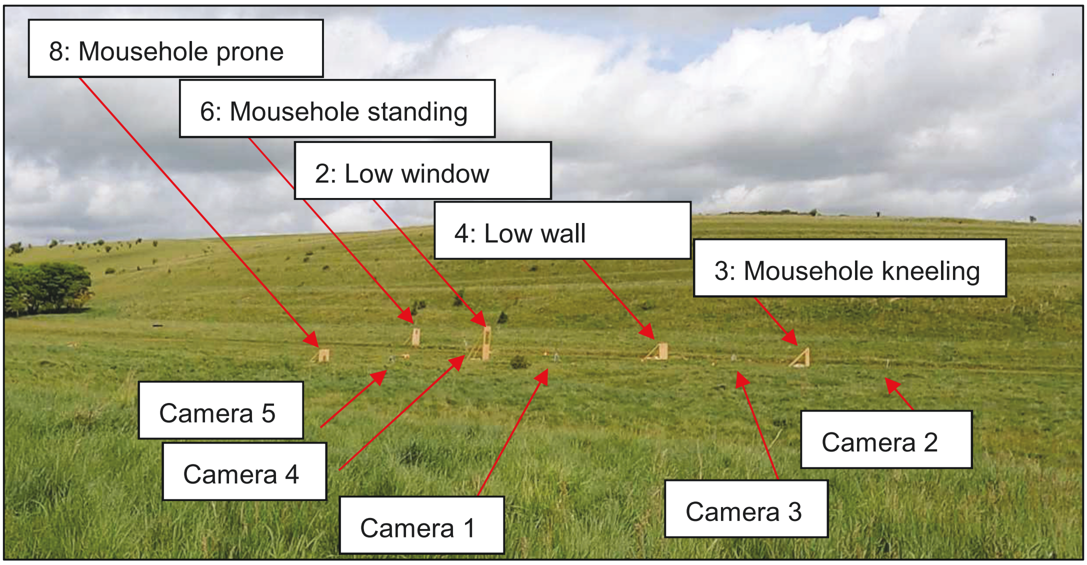

Figure 7 - Location of obstacles and cameras (taken from the overview (camera 7) location)

Video footage was assessed post trial to record timing of each action (APPENDIX B).

A still image example of the footage is provided in Figure 8. The video was time synced and segmented into quarters displaying the footage time for analysis purposes (e.g. 05:45:46). The top left video displayed real time (e.g. 11:12:07 am) and footage from the participants' helmet camera. The bottom left video displayed footage from the overview camera. The bottom right displayed video from the instructors' helmet camera. The top right video displayed video from each of the 5

[2] Go Pro Hero 9, 4k (3840 x 2160) resolution, 60 frames per second. Cameras 1-7: linear and horizontal levelling f.19-34 mm. Camera 8: Linear f.19-39 mm.

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obstacle cameras, with the footage changing when participants entered/exited the obstacles' vicinity.

Figure 8 - Still image of video footage used for timing data

2.5.3 Timing App

In addition to capturing actions using video, an Android based app developed by Defence Research and Development Canada (DRDC) was also trialled. The output from this was not used in the analysis of the UK pilot trial data. A screen shot of the app is presented in Figure 9. It is recommended that the app be used to record the timing of actions/activities whilst reviewing the video footage.

2.5.4 Metrology

Distances between firing points and targetry was measured using a trundle wheel (Figure 10), attempts were made to confirm distances with a laser distance measurer DTAPE DT100[3], serial number 2020G013182 (Figure 11). However, positional accuracy of the hand-held laser at extended range, as well sunlight obscuring the laser resulted in this method being abandoned and distances re-confirmed with the trundle wheel. It is recommended that a military laser range finder (LRF) is utilised in the future for this purpose.

Wind speed was measured using a Kestrel 2500[4] wind and temperate meter, serial number 2605281 (Figure 12).

[3] Accuracy: ±1.6 mm.
[4] Accuracy: Wind: ±3%. Temperature: ±0.5°C.

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The light level was measured using an AOPUTTRIVER AP-881E digital lux meter[5], serial number 202100091541 (Figure 13).

Meteorological and light level data is presented in APPENDIX E. Temperature data was provided by the Larkhill Medical Centre.

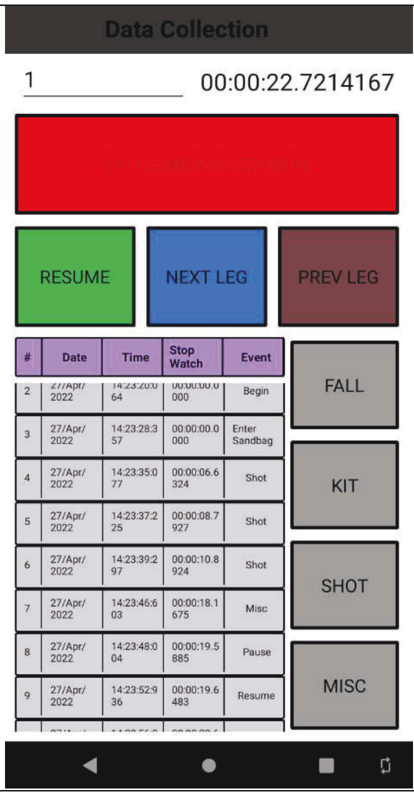

Figure 9 - DRDC Android timing app

Figure 10 - Trundle wheel

[5] Accuracy: ≤10,000 Lux, ±4% rdg ±0.5% f.s. ≥10,000 Lux, ±5% +10 digits.

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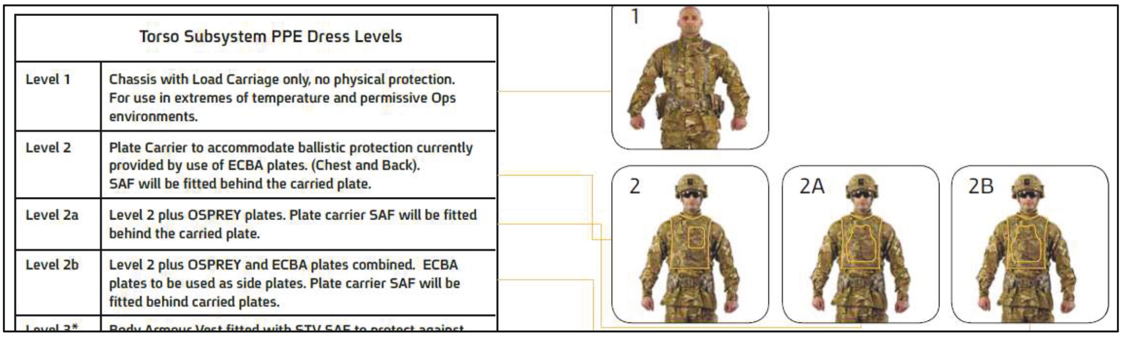
Figure 11 - Laser distance measurer DTAPE DT100	Figure 12 - Kester 2500 wind and temperate meter	Figure 13 - AOPUTTRIVER AP-881E digital lux meter

2.6 Participant Equipment

Participants completed the pilot course in VIRTUS dress level 2. This consisted of the following equipment:

- Boots (issued or self-purchased);
- Personal Clothing System (PCS) trousers;
- Under Body Armour Combat Shirt (UBACS);
- VIRTUS Scalable Tactical Vest (STV) + soft armour (front and rear) + Mk2 contoured plates (front and rear);
- VIRTUS helmet;
- VIRTUS webbing;
- Hearing protection (3M Peltor ComTac XP or 3M Combat Arms Ear Plugs (CAEP)).

The description of VIRTUS dress level 2, as per the VIRTUS User Assembly, Care and Maintenance Instructions [5], is provided in Figure 14.



Torso Subsystem PPE Dress Levels	
Level 1	Chassis with Load Carriage only, no physical protection. For use in extremes of temperature and permissive Ops environments.
Level 2	Plate Carrier to accommodate ballistic protection currently provided by use of ECBA plates. (Chest and Back). SAF will be fitted behind the carried plate.
Level 2a	Level 2 plus OSPREY plates. Plate carrier SAF will be fitted behind the carried plate.
Level 2b	Level 2 plus OSPREY and ECBA plates combined. ECBA plates to be used as side plates. Plate carrier SAF will be fitted behind carried plates.
Level 3*	Body Armour Vest fitted with STV SAF to protect against

Figure 14 - VIRTUS dress level 2

2.7 Participant Demographics

Participants were randomly assigned a participant number (1-6) at the start of the trial.

The following numbers of participants were available for the two live fire days of the pilot trial:

- Day 1 (17 May 2022) - 6 participants firing the SA80 L85 A3;
- Day 2 (18 May 2022) - 4 participants (participants 1 and 4 withdrew from the trial) firing the SA80 L85 A2.

Due to only 4 participants being available on day 2, a comparison of both treatments (SA80 L85 A2 and A3) for participants 1 and 4 was not possible. However, all data is presented for completeness in APPENDIX C.

On day 1, the average age of all 6 participants was 25 years old (SD 4.1), average height was 180.0 cm (SD 3.0), and weight averaged 79.0 kg (SD 6.3). Two participants were left handed and 4 were right handed. The average time since completion of Phase 2 training was 2 years. Three participants held the rank of Lance Corporal (LCpl)[6], and three were Riflemen[7]. Two of the LCpls had conducted operations/training in Estonia and Ukraine.

On day 2, the average age of the 4 participants was 23 years old (SD 3.8), average height was 179.0 cm (SD 3.4), and weight averaged 78.0 kg (SD 4.1). All participants were right handed. The average time since completion of Phase 2 training was 1.5 years (one participant did not report their Phase 2 completion date). Two participants held the rank of Lance Corporal (LCpl), and two were Riflemen. One of the LCpl’s had conducted operations/training in Estonia and Ukraine.

The participants’ demographics are summarised in APPENDIX F.

[6] NATO rank: OR-3.
[7] NATO rank: OR-2.

2.8 Target Layout

A total of eight Saab IMLF targets were used and are illustrated in the schematic provided in Figure 15. This includes one short, two medium and two long range targets, plus 3 Close Quarter Battle (CQB) targets. All distances displayed are measured from firing point 1.

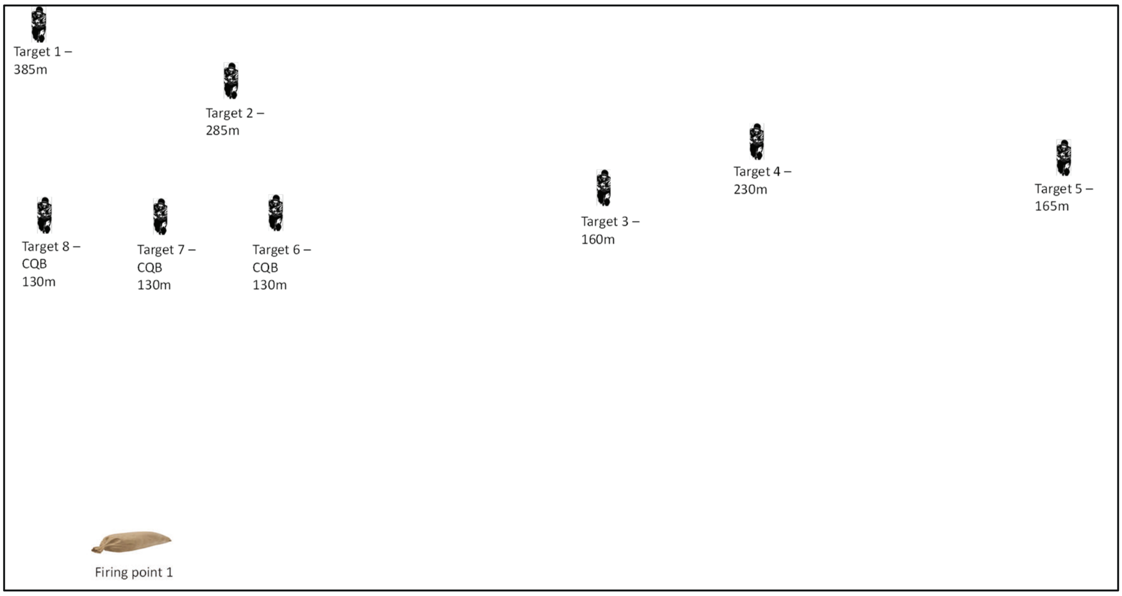


Figure 15 - Saab IMLF target

Targets were laid out in the following planned configuration (from firing point 1), with stated distances from firing point 1 to each target:

- Long range target 1: 400 m;
- Long range target 2: 300 m;
- Medium range target 1: 180 m;
- Medium range target 2: 250 m;
- Short range target: 185 m.

Discrepancies exist between the planned target distances to the actual target distances presented in Figure 15, due to the use of a trundle wheel to measure the distance compared to the GPS measurements in Figure 15. The use of an LRF would have provided more accurate measurements with less inherent error than a trundle wheel or GPS. It is recommended that an LRF is used to confirm target distances in future versions of the course.

Table 1 provides the planned obstacle to target distances, with the position of firing point 1 denoted by x, y 0,0. The cells are colour coded to indicate S (Short), M (Medium), or L (Long) range distances from the firing points' perspective for that obstacle. Minor modifications to the exact targets being engaged (as listed in Table

1) were required due to line of sight and limited arcs of fire at the trial location. The targets engaged during the pilot trial are presented in Section 2.9 and APPENDIX B.

										Target 1		Target 2		Target 3		Target 4		Target 5	
Obstacle	Firing Point	Distance		Requirement						Long Range 1		Long Range 2		Medium Range 1		Medium Range 2		Short Range	
		x	y							Distance	Angle	Distance	Angle	Distance	Angle	Distance	Angle	Distance	Angle
1	Sandbag prone	0	0	L	L	M				400.1	1.4	300.7	-3.8	182.5	-9.5	253.2	9.1	194.5	-18
2	Low window	17	99	M	S	M	M	M	L	302.7	5.2	201.5	-0.7	101.3	-7.2	153.2	8.5	96.4	-26.2
3	Mousehole kneeling	25	79	M	L					323.1	6.3	201.5	1.5	101.3	-2.6	171.8	4.9	111.7	-18.1
4	Low wall	29	89	M	L					313.8	7.2	211.6	2.5	91.4	-0.6	161.8	3.9	101.2	-17.8
5	Sandbag prone	30	104	L	M					299	7.6	196.6	2.8	76.4	-0.3	146.8	4.1	86.9	-20.5
6	Mousehole standing	35	113	S	M	S	M			290.6	9	187.6	4.7	67.2	4.5	137.1	2	76.1	-18.9
2 (back to)	Low window	20	99	M	S	S	S	M	M	303	5.7	201.5	0	82.1	-7.1	152.8	7.6	95.4	-24.9
7	Sandbag kneeling	18	104	M	S					297.8	5.4	196.5	-0.6	77.5	-9	148.2	8.6	91.8	-27.3
8	Mousehole prone	10	105	M						295.4	3.9	195	-2.9	77.3	-15	147.8	11.7	94.1	-32.1

Key			
Distance	S	M	L
Angle	Narrow	Wide	

Table 1 - Target Layout

2.9 Target Information

The Saab IMLF smart targetry system was used to measures live fire effects within a Tactical Engagement Simulation (TES) communications system.

The smart targetry system operates in tandem with Saab user-worn live simulation instrumentation and collect the following data points:

- Time/geo stamped fire and hit events;
- Using the Saab Algorithmic Pairing Program, attributes hits on the target to individual riflemen or machine gunners;
- Measures holistic lethality and suppression by tracking players on geo mapping, in conjunction with target simulations;
- Captures ammunition natures fired and measures effect of each round;
- Measures weapon system, individual and collective performance and effectiveness.

The IMLF system comprises of the following components:

- Saab Instrumented Target (SIT);
- Saab LOMAH Bar;
- Wireless Target System (WTS);
- Saab Excon;
- Saab Data Acquisition Network (DAN) Communication system;
- Personal Detection Device (PDD);
- Small Arms Transmitter (SAT).

The system concept is illustrated in Figure 16.

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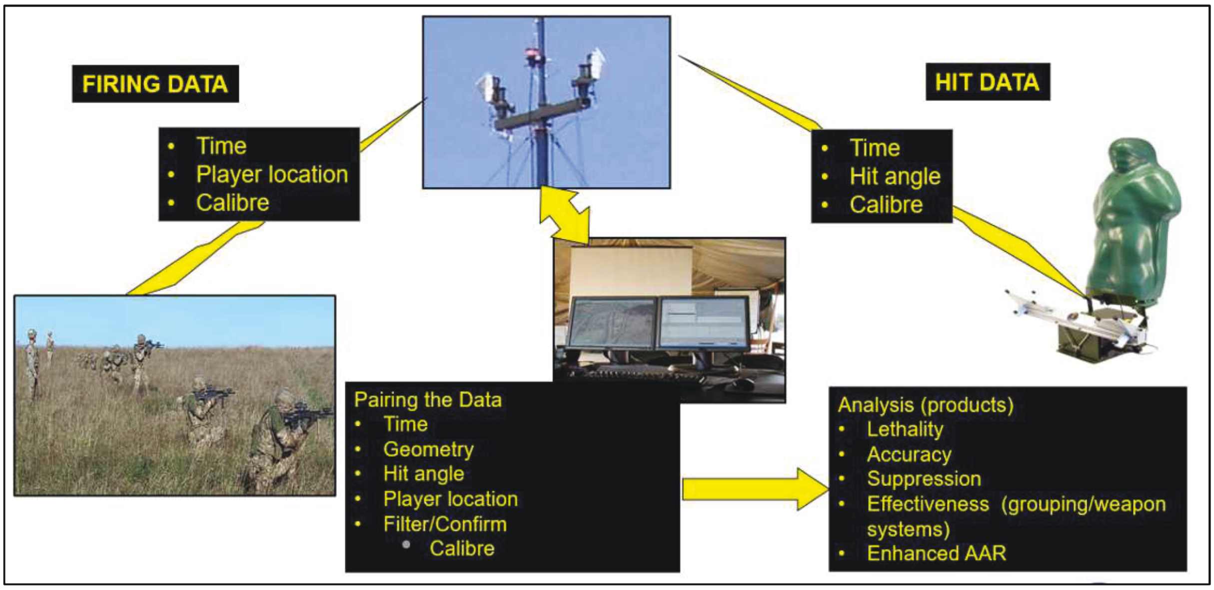

Figure 16 - Saab IMLF System Design

The Saab LOMAH bar must have the following capabilities:

- Interface with SIT and WTS to provide real time fire data to Excon;
- Provide a reliable sonic microphone detection system;
- Provide a programmable, adjustable detection area, typically 5 m x 3 m;
- Provide a detection angle of 60° off the centre line;
- Measure supersonic suppression data up to 640 m for 7.62 mm ammunition.

2.10 Course Layout

Section 2.2 describes the firing points, obstacles and SWEAT course.

Initial set-up of the course took ~4.25 hours with 5 people, following the layout distances provided in Table 1.

A total of 14 firing points are illustrated in the schematic in Figure 17. The numbers preceding the firing position denotes the serial, and the numbers proceeding the firing position denotes the target number being engaged. e.g. Serial 22, prone position, target 1.

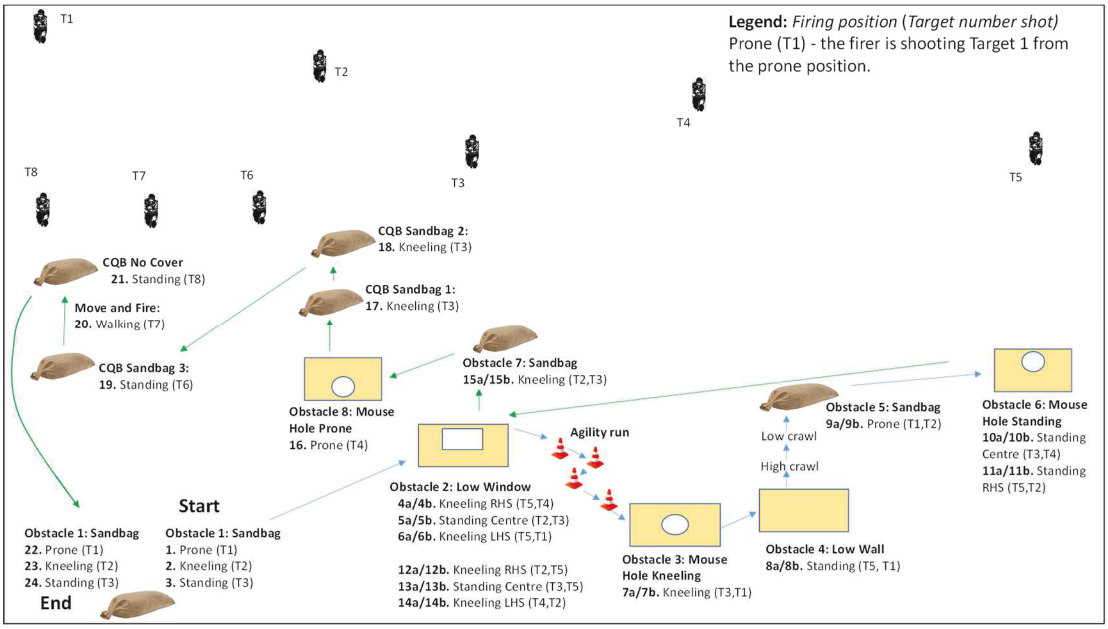

Figure 17 - Course schematic

2.11 Questionnaire

Following the completion of the SWEAT course for each variant of the SA80 L85, each participant was asked to complete a questionnaire to capture subjective feedback relating to the course itself, the equipment being compared, the target, activities at each obstacle, and the ability to list their likes, dislikes and improvements to the SWEAT course. A blank copy of the questionnaire is provided in APPENDIX G.

The participants were requested to rank the following questions on a Likert scale 1 (negative) to 10 (positive):

1. Question 1: How well did you feel you could move through the course overall?
2. Question 2: How well could you establish a coherent sight picture with your weapon?
3. Question 3: How well did you feel you could engage targets at long, medium and short ranges?
4. Question 4: Did you experience any issues with the following throughout the course?
5. Question 5: Please list likes, dislikes or changes/improvements you would make to the course.

Participants were also provided with the opportunity to provide their own comments following each question. These are provided in Section 5.3.

2.12 Trial Equipment

The following instrumentation/equipment was required:

- 8 x Saab IMLF targets and (LOMAH) bars;
- 8 x Go Pro Hero 9's;
- 8 x 400 GB Micro SD cards for Go Pro's and spare batteries;
- Portable power for recharging Go Pro batteries and Solar Panel[8];
- Trundle wheel (Figure 10);
- Laser distance measurer (Figure 11);
- Wind/temperature sensor (Figure 12);
- Lux meter (Figure 13);
- 40 sandbags for firing points and weighing obstacles down.

The following instrumentation/equipment was not required as it either did not work or was not useful:

- Laminated firing point instructions attached to each firing point – these were too wordy and the Range Conducting Officer (RCO) read the actions to the participant from their own notes;
- Go Pro remotes – Go Pro's were too far away and the remote was unreliable.

2.13 Trial Team Feedback

The following feedback was from the Dstl trials team:

- Positive
  - *The course was easier and faster to lay-out than envisaged;*
  - *Positive feedback from the participants helped to motivate them;*
  - *All equipment worked well, including the management of turning on/off the Go Pro's once a routine was quickly established.*
- Negative / Improvement
  - *Long grass and uneven ground made it difficult for all;*

[8] A Jackery Explorer 1000 and Jackery SolarSage 100W Solar Panel were used.

- *Signage on the firing points indicating firing position and location of the firing positions at each obstacle would have sped up the firing process rather than the RCO instruct the participant verbally;*
- *Targetry was adequate, but more planning could have made the process of exposing and dropping targets at the right time/impact count more fluid and speed up the course;*
- *An LRF would have sped up the obstacle set-up time as well and provided the most accurate distance measurement compared to GPS or a trundle wheel;*
- *At times, the RCO/instructor obscured the view of the obstacle cameras;*
- *A 360°/wide field of view camera mounted on the participant would have provided better indication of their actions to help extract timings;*
- *The wall and window obstacles need to be more study to allow the participant to negotiate them;*
- *Forced magazine changes provide a standardised method for data collection;*
- *It needs to be clear in whether a firing position is supported or unsupported.*
- *Need to add a rationale to why the course has certain parts (e.g. final sandbag measures fatigue), so when others set up the course they know what they are measuring and why.*
- *If the course cannot be set-up in the specific way, users know what their limitations are.*
- *The first two runs of the course had instances where the soldiers were anticipating which target would appear as they could hear the instructors' command to Saab to lift up the target. In subsequent runs, the instructor stood further back to avoid the soldiers from reacting before the target appeared;*
- *The participants could benefit from a dry 'familiarisation run' of the course to practice movement and firing positions.*
- *Recommend experimental design to limit learning effects;*
- *At the Low Window (primarily on the left hand side) participants had to break cover to shoot around the obstacles support (targets 4 and 5) due to blocking line of sight. A possible solution involved redesigning obstacle or target placements;*

- *LEAP obstacle course has specifications for a sturdier low wall and window obstacles which could implemented for SWEAT;*
- *If bullets become subsonic, the LOMAH bars may not register the firing (e.g. beyond 500-600 m for 5.56 mm).*
- *Targets that were down, still could record shots. This can easily be mitigated by cross-referencing with timestamps and filtering data.*

The following feedback was from the Infantry Trial and Development Unit (ITDU) RCO:

- Positive:
    - *Tests the soldiers' marksmanship;*
    - *The firer has to scan for targets instead of them popping up in their line of sight;*
    - *Makes the soldier think about how to best utilise the cover available to them;*
    - *Tests the soldiers' individual weapon drills;*
    - *Fatigues the soldier towards the end of the course (more realistic).*

- Negative / Improvement:
    - *Not course specific but the targetry used was inadequate (target needs to stay down once hit otherwise it confuses the firer);*
    - *All obstacles maybe to have two exposures (low mousehole had one) as it would simplify to the firer on what he needs to shoot at each obstacle and would cut time in what the RCO has to brief each time the firer gets to a new obstacle;*
    - *A definitive fire position at each obstacle. Whether this is supported / unsupported. The majority of the firers over the two days were using nearly all the obstacles to support their rifle. For example, firing from the window should be a foot back from the window in a tactical sense;*
    - *A time on how long it takes the firer to shoot the target could maybe be implemented. There were numerous times the firers could take up to 20-30 seconds before firing. This was especially prevalent when firing in the standing position which had no cover;*
    - *Obstacles could be sturdier, which would enable the firer to possibly climb the wall obstacle instead of going round it.*

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3 Data Management

3.1 Video Recording

The 400 GB SD cards used in each Go Pro adequately captured footage for all 10 runs. Each run produced 30-35 minutes of raw video which was ~25 GB.

Three personnel turned on and pressed record for all camera's immediately prior to the run starting. As soon as it was clear, the cameras were stopped, turned off and batteries changed, as they generally last ~60 minutes.

Go Pro's save video to the SD card in 4 GB files. Following the completion of the trial, these were moved into file system containing the weapon variant, participant number and camera number, each identified by their start and end time. An example of this is presented in Figure 18.

« A2 › Participant_1 › Camera_1 — Search Camera_1

Name	Date	Type	Size	Length
GX010007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,324 KB	00:05:20
GX020007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,875 KB	00:05:20
GX030007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,406 KB	00:05:20
GX040007	18/05/2022 11:11	MP4 Video File (VLC)	3,915,972 KB	00:05:20
GX050007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,940 KB	00:05:20
GX060007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,620 KB	00:05:20
GX070007	18/05/2022 11:11	MP4 Video File (VLC)	3,916,062 KB	00:05:20
GX080007	18/05/2022 11:11	MP4 Video File (VLC)	549,324 KB	00:00:44

Figure 18 - File system used for the pilot trial

A log of each video file from all cameras was also created in MS Excel, in case any accidental deletion or modifications occurred to the original files. An example of this is presented in Figure 19. This also made identifying missing footage easier.

	Camera	Filename	Date	Time
Participant 1	1	GX010007	18/05/2022	10:16
		GX020007	18/05/2022	10:22
		GX030007	18/05/2022	10:27
		GX040007	18/05/2022	10:32
		GX050007	18/05/2022	10:38
		GX060007	18/05/2022	10:43
		GX070007	18/05/2022	10:48
		GX080007	18/05/2022	10:48
Participant 2		GX010008	18/05/2022	11:06
		GX020008	18/05/2022	11:11
		GX030008	18/05/2022	11:17
		GX040008	18/05/2022	11:22
		GX050008	18/05/2022	11:27
		GX060008	18/05/2022	11:31
		-	18/05/2022	-
Participant 3		GX010009	18/05/2022	12:03
		GX020009	18/05/2022	12:09
		GX030009	18/05/2022	12:14
		GX040009	18/05/2022	12:19
		GX050009	18/05/2022	12:25
		GX060009	18/05/2022	12:26
Participant 4		GX010010	18/05/2022	12:32
		GX020010	18/05/2022	12:37
		GX030010	18/05/2022	12:43
		GX040010	18/05/2022	12:48
		GX050010	18/05/2022	12:54
		GX060010	18/05/2022	12:59
		-	18/05/2022	-

	Camera	Filename	Date	Time
Participant 1	2	GX010021	18/05/2022	10:16
		GX020021	18/05/2022	10:22
		GX030021	18/05/2022	10:27
		GX040021	18/05/2022	10:32
		GX050021	18/05/2022	10:38
		GX060021	18/05/2022	10:43
		GX070021	18/05/2022	10:48
		-	18/05/2022	-
Participant 2		GX010022	18/05/2022	11:07
		GX020022	18/05/2022	11:12
		GX030022	18/05/2022	11:18
		GX040022	18/05/2022	11:23
		GX050022	18/05/2022	11:28
		GX060022	18/05/2022	11:34
		GX070022	18/05/2022	11:34
Participant 3		GX010023	18/05/2022	12:06
		GX020023	18/05/2022	12:11
		GX030023	18/05/2022	12:16
		GX040023	18/05/2022	12:22
		GX050023	18/05/2022	12:27
		-	18/05/2022	-
Participant 4		GX010024	18/05/2022	12:34
		GX020024	18/05/2022	12:40
		GX030023	18/05/2022	12:45
		GX040023	18/05/2022	12:50
		GX050023	18/05/2022	12:56
		GX060021	18/05/2022	13:00
		-	18/05/2022	-

	Camera	Filename	Date	Time
Participant 1	3	GX010024	18/05/2022	10:15
		GX020024	18/05/2022	10:21
		GX030024	18/05/2022	10:26
		GX040024	18/05/2022	10:31
		GX050024	18/05/2022	10:37
		GX060024	18/05/2022	10:42
		GX070024	18/05/2022	10:47
		GX080024	18/05/2022	10:48
Participant 2		GX010025	18/05/2022	11:06
		GX020025	18/05/2022	11:11
		GX030025	18/05/2022	11:17
		GX040025	18/05/2022	11:22
		GX050025	18/05/2022	11:27
		GX060025	18/05/2022	11:32
		-	18/05/2022	-
Participant 3		GX010026	18/05/2022	12:04
		GX020026	18/05/2022	12:09
		GX030026	18/05/2022	12:15
		GX040026	18/05/2022	12:20
		GX050026	18/05/2022	12:25
		GX060026	18/05/2022	12:26
Participant 4		GX010027	18/05/2022	12:33
		GX020027	18/05/2022	12:38
		GX030027	18/05/2022	12:43
		GX040027	18/05/2022	12:49
		GX050027	18/05/2022	12:54
		GX060027	18/05/2022	12:58
		-	18/05/2022	-

Figure 19 - Video log example

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3.2 Lethality Data Capture

Lethality data consisted of timestamps and shot vector data. These were captured by the Saab Small Arms Transmitter (SAT) acoustic device attached to each participant’s weapon barrel and the eight Saab IMLF targets set out throughout the course:

- The SAT had an integrated GPS so that it could provide longitude and latitude coordinates as well as timestamps whenever shots were fired;
- Saab targets were accompanied by a LOMAH bar that could detect any passing shots within ~2 m of the target, providing a timestamp and shot vector data.

The timestamp data from both of these devices enabled an aggregation of these two datasets into one, as presented in Figure 20. Cells B-H were records from the GPS-integrated acoustic device. Cells I-V were from the Saab targets. The distance to target was then calculated in cell W using spherical trigonometry with the recorded GPS coordinates.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Event Time	Firer	Player Sim	Log Index	Latitude	Longitude	Ammunition (	Target Eve	Target	Target Play	Target Log	Target Lati	Target Lon	Hit Result	Horizontal	Vertical Pc	Aspect	Est. Calibe	Lifter Statu	Bearing	Bearing Di	Distance
2	17/05/2022 11:31:28	1	6110	83	51.26477	-1.83289	Assault Rifle															
3	17/05/2022 11:31:34	1	6110	85	51.26477	-1.83289	Assault Rifle															
4	17/05/2022 11:31:39	1	6110	87	51.26477	-1.83289	Assault Rifle															
5	17/05/2022 11:31:43	1	6110	89	51.26477	-1.83289	Assault Rifle															
6	17/05/2022 11:31:46	1	6110	91	51.26477	-1.83289	Assault Rifle	11:31:45	Target # 1	6510	89	51.26486	-1.83844	Hit No Kill	-0.13	-0.29	5.76	5.56 mm	Up	91.4	1.7	390
7	17/05/2022 11:32:41	1	6110	93	51.26477	-1.83289	Assault Rifle															
8	17/05/2022 11:32:45	1	6110	95	51.26477	-1.83289	Assault Rifle	11:32:45	Target # 2	6516	209	51.26512	-1.837	Hit No Kill	-0.25	0.13	0.12	5.56 mm	Up	97.6	2.5	290
9	17/05/2022 11:32:50	1	6110	97	51.26477	-1.83289	Assault Rifle	11:32:49	Target # 2	6516	210	51.26512	-1.837	Hit No Kill	-0.13	0.19	0.59	5.56 mm	Up	97.6	2	290
10	17/05/2022 11:32:54	1	6110	99	51.26477	-1.83289	Assault Rifle	11:32:53	Target # 2	6516	211	51.26512	-1.837	Miss: Near	0.63	-0.05	6.47	5.56 mm	Up	97.6	-3.9	290

Figure 20 - First nine records of aggregated data from the WTS device and Saab targets

Aggregating the two datasets relative to their timestamps enabled cross validation, enabling missing data to be identified more easily. Most anomalies were shots that failed to be registered by the LOMAH bar due to poor accuracy (misses). These shots were nonetheless included within the analysis with a “Miss: Far” tag so that lethality metrics were not subjected to survivorship bias. For example, if only 5 out of 10 shots were registered with all 5 hitting the target, then the percentage of hitting metric would be falsely calculated as 100% instead of 50%.

Figure 21 shows the first nine records of the dataset used for lethality. Changes to the raw data (distance calculations and placeholders for missing data) are in red.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Event Time	Firer	Player Sim	Log Index	Latitude	Longitude	Ammunition (	Target Event	Target	Target Play	Target Log	Target Lati	Target Lon	Hit Result	Horizontal	Vertical Pc	Aspect	Est. Calibe	Lifter Statu	Bearing	Bearing Di	Distance
2	17/05/2022 11:31:28	1	6110	83	51.26477	-1.83289	Assault Rifle	11:31:28	Target # 1	6510	85	51.26486	-1.83844	Miss: Far	0	-3	5.76	5.56 mm	Up	91.4	1.7	390
3	17/05/2022 11:31:34	1	6110	85	51.26477	-1.83289	Assault Rifle	11:31:34	Target # 1	6510	86	51.26486	-1.83844	Miss: Far	0	-3	5.76	5.56 mm	Up	91.4	1.7	390
4	17/05/2022 11:31:39	1	6110	87	51.26477	-1.83289	Assault Rifle	11:31:39	Target # 1	6510	87	51.26486	-1.83844	Miss: Far	0	-3	5.76	5.56 mm	Up	91.4	1.7	390
5	17/05/2022 11:31:43	1	6110	89	51.26477	-1.83289	Assault Rifle	11:31:43	Target # 1	6510	88	51.26486	-1.83844	Miss: Far	0	-3	5.76	5.56 mm	Up	91.4	1.7	390
6	17/05/2022 11:31:46	1	6110	91	51.26477	-1.83289	Assault Rifle	11:31:45	Target # 1	6510	89	51.26486	-1.83844	Hit No Kill	-0.13	-0.29	5.76	5.56 mm	Up	91.4	1.7	390
7	17/05/2022 11:32:41	1	6110	93	51.26477	-1.83289	Assault Rifle	11:32:41	Target # 2	6516	208	51.26512	-1.837	Miss: Far	0	-3	0.12	5.56 mm	Up	97.6	2.5	290
8	17/05/2022 11:32:45	1	6110	95	51.26477	-1.83289	Assault Rifle	11:32:45	Target # 2	6516	209	51.26512	-1.837	Hit No Kill	-0.25	0.13	0.12	5.56 mm	Up	97.6	2.5	290
9	17/05/2022 11:32:50	1	6110	97	51.26477	-1.83289	Assault Rifle	11:32:49	Target # 2	6516	210	51.26512	-1.837	Hit No Kill	-0.13	0.19	0.59	5.56 mm	Up	97.6	2	290
10	17/05/2022 11:32:54	1	6110	99	51.26477	-1.83289	Assault Rifle	11:32:53	Target # 2	6516	211	51.26512	-1.837	Miss: Near	0.63	-0.05	6.47	5.56 mm	Up	97.6	-3.9	290

Figure 21 - First nine records of the dataset used for analysing lethality within the pilot trial

3.3 Mobility Data Capture

Mobility data consisted of timestamps when participants started and finished all SWEAT course obstacles. The NATO SWEAT Panel had provided a template data capture sheet for when timestamps of each participant needed to be recorded. A completed sheet is presented in APPENDIX D. These timestamps indicated the total course completion time, as well as the time taken through each mobility obstacle.

It is recommended to automate mobility data capture in future trials with well-placed sensors. However, in this pilot trial these timestamps were manually recorded by reviewing video footage (Figure 8).

3.4 Data Processing Tools and Techniques

Analysing the lethality and mobility data was conducted using the statistical software R in line with NATO best practice [1]. All datasets were stored in Microsoft Excel.

A check for normality and equality of variance on the x and y shot vector data was conducted in order to determine which statistical tests and metrics were most appropriate for conducting analysis.

Due to only four participants running both treatments, most standard statistical tests and metrics were inappropriate. In the analysis of this pilot trial hit percentage was considered a more appropriate metric than probability of hit (PHit), likewise circular error probable (CEP) was substituted by a confidence ellipse (CE). Section 4.1 defines how each metric was calculated.

This trial captured data from participants running through the same course multiple times as treatments. A low participant count meant there was low confidence in comparing mean results of all participants, as it would not be fully representative of an average participant. Instead, comparative tests (such as Wilcoxon, Kruskal-Wallis or Friedman tests) are included in this report as they bolster the likelihood of finding statistically significant differences across treatments.

Overall, the methodology used in this report provides context as to how one should conduct data analysis on future SWEAT trials.

3.5 Ethics

This study was conducted in accordance and approval of the Ministry of Defence Research Ethics Committee (MODREC), as per JSP 536 [6].

The UK SWEAT Pilot Trial received a MODREC favourable opinion 8 March 2022 [7][8], reference 2092/MODREC/21.

3.6 Participants

A briefing to the volunteer participants was conducted 27 April 2022. The briefing is provided in APPENDIX H.

During this brief participants were requested to complete a consent forms:

- Read and understand the participant information sheet (PIS) (APPENDIX I);
- Read and sign the consent form for participants in research studies (APPENDIX J);
- Read and sign the arrangements for payment of no-fault compensation (APPENDIX K);
- Read and sign the consent form for use of video, audio and photography (APPENDIX L).

Participants who were not present at the brief, or those that were swapped by their unit due to conflicting demands, were briefed on the morning of 17 May 2022 and completed the PIS and other associated consent forms at the start of the trial.

4 Analysis Methodology

4.1 Measures of Performance

The following lethality metrics were analysed:

- Lethality (results in Section 5.1):
  - Hit Percentage;
  - Mean point of impact (MPI);
  - PHit[9];
  - CEP[10];
  - Time to Engage.
- Mobility (results in Section 5.2):
  - Time to complete each mobility obstacle;
  - Time to complete entire course.

Hit percentage was calculated by dividing the number of hits by the total number of shots fired. MPI, PHit and CEP were calculated as defined in Chapter 2.4 of NATO D14. Time to engage was defined as the time difference between the target popping up and the first shot fired at it.

Tests for normality and equality of variance in x and y shot vectors were considered to determine whether MPI, PHit, CEP were appropriate. With more participants the population mean for each metric could be compared across treatments, however this is best for larger sample sizes (>20 participants). Instead, comparative tests like Wilcoxon (the non-parametric alternative to paired t-test) were conducted in order to better interrogate differences. For example, seeing whether all four participants improved in hit percentage between treatments rather than whether the average hit percentage of all four improved. The key difference between the two is that the latter is highly influenced by anomalies (See Section 4.2).

The course offers the opportunity to investigate tiredness factors by repeating the first three firing serials at the very end of the course. As such, the above metrics were also calculated for data filtered for just these firing serials.

The course recommended categorising distances into four categories (CQB, S, M and L). After further investigation it was decided that an additional Extra Long (XL) category should be added to differentiate between targets at ~300 m and targets at ~400 m. Figure 22 illustrates the density of shots fired at each target over the second

[9] PHit was not calculated due to low sample size

[10] Confidence Ellipses at 90% confidence intervals (CE_{90}) were calculated instead due to variance in x and y shot vectors likely not being identical across groups

day of the trial, which had four participants. If more participants ran the course, further discrepancies in range could be viable.

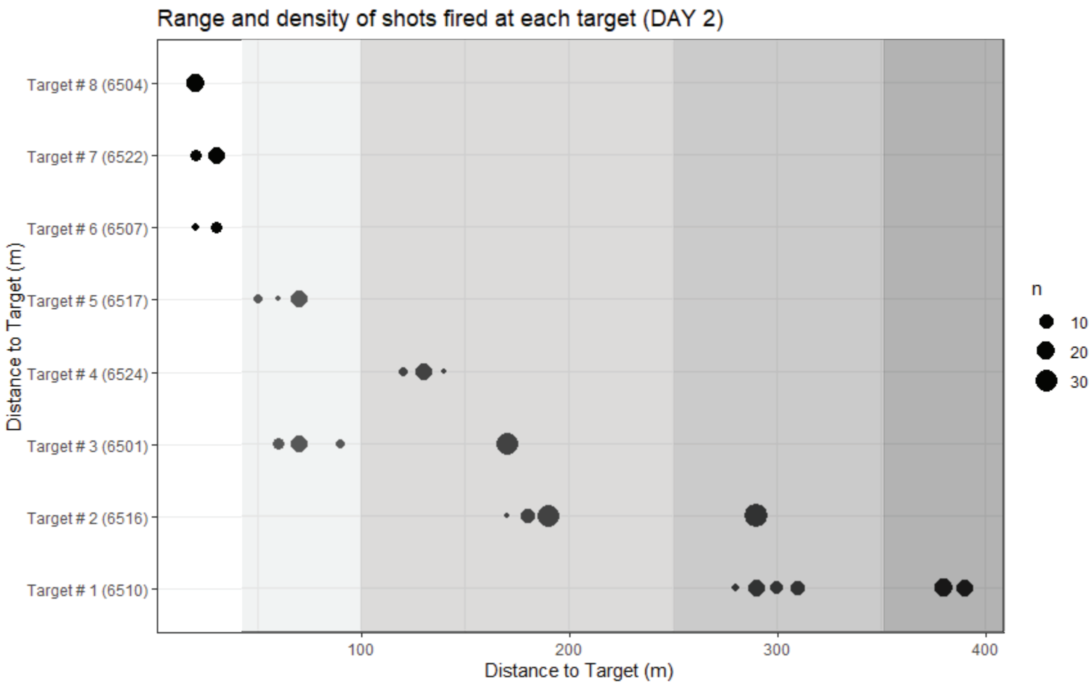

Figure 22 - Range and density of shots fired for day 2

4.2 Caveats

In this pilot trial, effects of learning the course were purposefully not mitigated by having all of each treatment recorded on separate days. As the two treatments tested were extremely similar (Section 2.3), it was therefore hypothesised that there would be little subjective and objective differences between the two beyond a potential learning effect. However, it is recommended that future iterations of this course adopts an experimental design that mitigates the learning effect.

On day 2 (A2 variant) a media camera crew were present to capture footage for social media. It is assumed that this likely encouraged participants to run faster.

Of the six participants that ran the course at least once, only four participants ran both treatments. The results presented in Section 5.1 and 5.2 mainly include four participants as comparative results reduces sampling biases and therefore improves the likelihood of finding meaningful differences.

Tests for statistically significant differences were also conducted where appropriate, however the low number of participants meant that most test results had low confidence. It is expected that with more participants and more distinct treatments, better conclusions could be drawn, such as sensitivity analysis between firing position, posture and distance to target across treatments.

4.3 Questionnaire Analysis

The following section describes the results from the subjective evaluation questionnaire answered by participants following each run through of the course.

Each question required a 7 scale Likert scale response from a negative response to a positive response.

Due to the small sample size (day 1 n=6, day 2 n=4) no statistical significance tests were conducted on the questionnaire data.

The results of the questionnaire are presented in Section 5.

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5 Results

This section presents results obtained from analysing the lethality and mobility data collected for the pilot trial. All results are generated by the statistical software R. Due to the small sample size (day 1 n=6, day 2 n=4) no statistical significance tests were inconclusive, however they are nonetheless provided to better demonstrate best practice for analysing data from future SWEAT trials.

5.1 Lethality

This section presents the results from the data collected from the Saab IMLF targets and SAT devices. As distance is often a key factor in accuracy and precision, all metrics were calculated across different distance categories (as defined in Figure 22).

Some metrics like MPI, PHit and CEP are inappropriate if certain assumptions about the data cannot be made. This includes the assumption of normality and equality of variance in x and y. Histograms of x and y shot vectors are presented by Figure 45 and Figure 46 and are used to investigate the assumptions of each metric. It was concluded that no merit would be gained by including PHit values alongside hit percentages. Likewise, confidence ellipses have been used instead of CEP.

5.1.1 Overview

Figure 23 illustrates an overview of all the shots registered against each distance category. It includes confidence ellipses at 90% (CE_{90}) to illustrate the smallest area that contains 90% of the shots. As hypothesised, there appears to be minimal differences between the two weapon configurations. Although a difference can be seen for XL (> 350 m), there is low confidence in how meaningful this is due to small sample sizes. Furthermore, shot group sizes follow a trend of increasing as the distance to target increases. CQB shots are an exception to this, likely due to this involving firing on the move shots. In the following subsections, all of these observations are investigated further with the metrics defined in Section 4.1

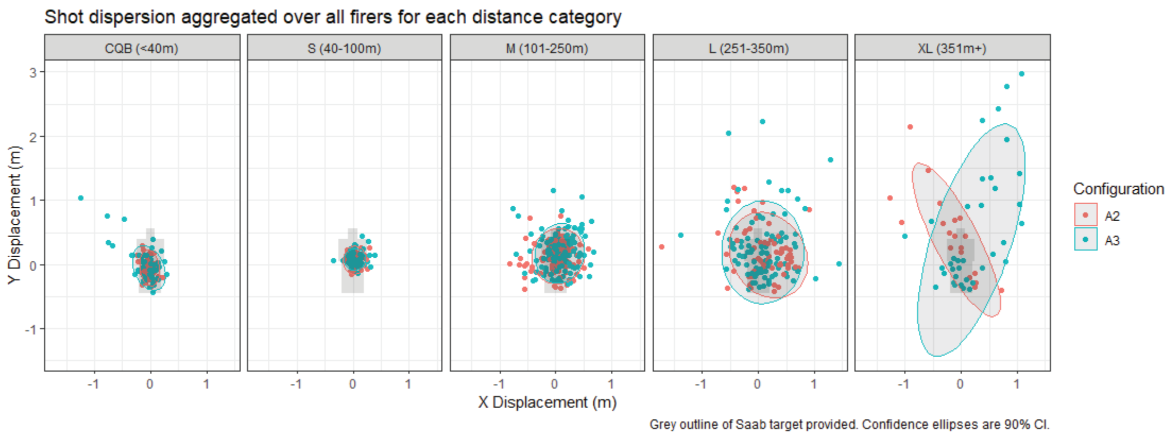

Figure 23 - Scatter graph of all shots across each distance category (with CE_{90})

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The total hits for all firers at each range across treatments are in Table 2 and Table 3.

	1	2	3	4	5	6
CQB (<40m)	9	11	12	7	11	9
S (40-100m)	11	11	12	11	12	11
M (101-250m)	14	14	16	12	12	11
L (251-350m)	6	4	9	5	8	1
XL (351m+)	2	0	6	0	6	0

Table 2 - Total hits per firer (A3)

	2	3	5	6
CQB (<40m)	12	12	10	11
S (40-100m)	11	12	10	11
M (101-250m)	14	15	16	12
L (251-350m)	3	6	10	1
XL (351m+)	4	3	0	0

Table 3 - Total hits per firer (A2)

5.1.2 Hit Percentage

Whilst Figure 23 shows that there are no clear differences in shot group size across treatments, reviewing hit percentages may prove more insightful as its calculation accounts for shots that were not registered by the Saab targets (which cannot be displayed in Figure 23). Table 4 numerically compares the hit percentage between treatments across all distances. There is no evidence to suggest that one treatment is better overall, however there are indicators that A3 might be better at longer ranges. To better investigate these observations, a Wilcoxon test is required.

	Configuration	
Distance	**A2**	**A3**
CQB (<40 m)	96% (47)	84% (70)
S (40-100 m)	96% (46)	89% (76)
M (101-250 m)	59% (97)	54% (146)
L (251-350 m)	27% (74)	30% (110)
XL (350 m+)	21% (33)	25% (56)

Table 4 - Hit percentage across distances per treatment (sample size)

Summarised in Table 5 are the p-values of three separate Wilcoxon tests. The first column has a total of 40 data points (2 treatments, 4 firers, 5 distances). The latter two columns are subsets that filter by distance to investigate differences within the first three rows in Table 4 and the last two rows. As all of these three tests have a p-greater than 0.10, there is insufficient evidence to suggest that there is a significant difference in hit percentage between treatments.

	Overall	CQB/S/M	L/XL
p-value	0.4008	0.2766	0.3937

Table 5 - Wilcoxon test results on hit percentages

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A table of the overall hit percentage for each firer is presented in Table 9 and identifies that those with the highest hit percentages fired the least total number of shots, whilst those with poor accuracy fired more. This phenomenon was due to several course targets that did not go down when first hit, allowing participants to then proceed to the next stage. As such, it is important to note the dependency between accuracy and total course completion time.

5.1.3 Mean Point of Impact

Figure 24 illustrates the MPI for each firer and is encircled by its CE_{50}. The overlapping circles are shaded in a manner that better illustrates the density of fall of shot for each configuration. Whilst all firers' MPI is on the target, Firer 2 and 6 have an MPI that deviated considerably from the centre. As such, the MPI for each firer was split across distance ranges and given in Figure 25. It shows that the shot data from these firers only deviated at ranges > 350 m (XL), rather than consistently.

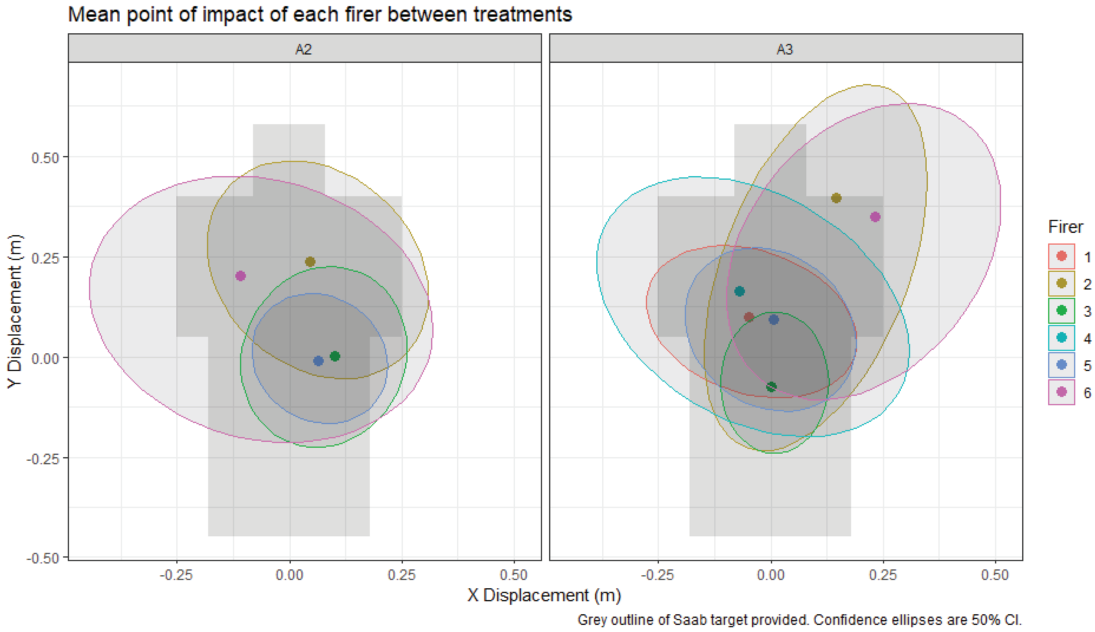

Figure 24 - Average location of a shot fired by each person

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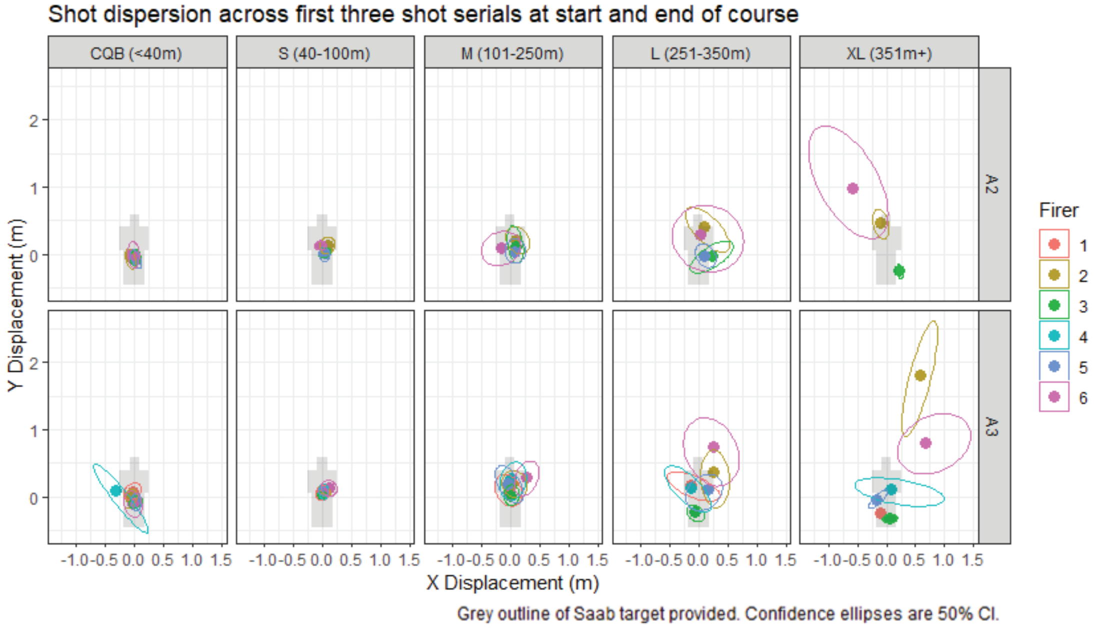

Figure 25 - Average location of a shot fired by each person at different ranges

A multivariate analysis of variance (MANOVA) test could be conducted to determine whether the MPI for each treatment are identical across variables. Alternatively, the Kruskal-Wallis or Friedman test could be used for low sample sizes. Testing for MPI across distance categories gave a p-value of <0.01, which implies a strong likelihood of significant differences. Investigating further with a pairwise Wilcoxon test identified that the vertical MPI for CQB was significantly lower than other distances (Figure 48). Figure 46 illustrates this by comparing the vertical fall of shot across distances. It is speculated that this difference is caused by firers choosing a slightly higher point of aim at further distances following a worse sight picture of the target.

5.1.4 Time to Engage

Figure 26 indicates that there is no difference in the median time taken to engage between treatments for each range up to 350m, but >350m A2 configuration takes 8 seconds longer to engage the target than the A3 configuration.

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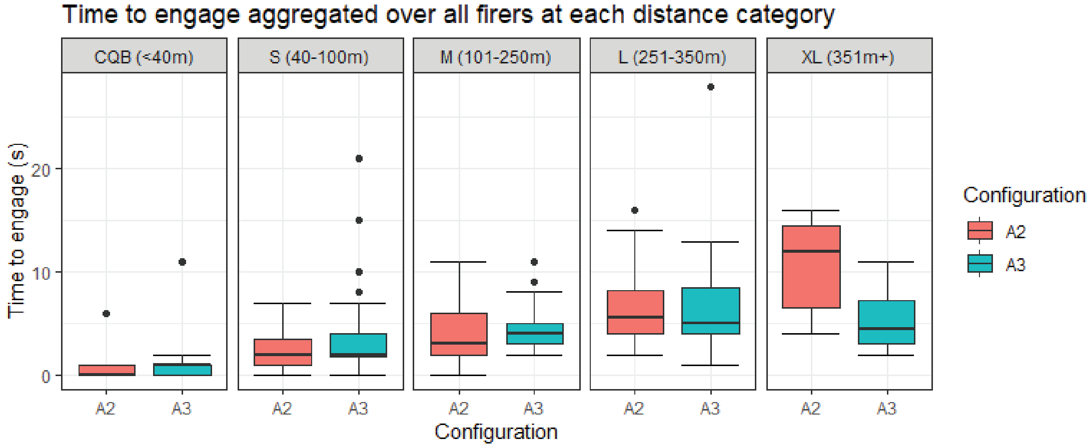

Figure 26 - Boxplot illustrating time to engage across different ranges

A Wilcoxon test was conducted on time to engage data for just distances beyond 350 m and gave a p-value <0.05. This means with 95% confidence the difference between the A2 and A3 at XL (351 m+) is statistically significant. As follows:

```
        Wilcoxon rank sum test with continuity correction

data:  filter(engage_df, dist_cat == "XL (351m+)", Configuration == "A2")$time_to_engage
 and filter(engage_df, dist_cat == "XL (351m+)", Configuration == "A3")$time_to_engage
W = 59.5, p-value = 0.03002
alternative hypothesis: true location shift is not equal to 0
```

A further pairwise Wilcoxon test across distances was conducted for each treatment and is given by Figure 49. For the A2 configuration, it concluded that time to engage between distances were all statistically different ($p<0.05$). For the A3 configuration, it evidenced that time to engage between M, L and XL were not statistically different.

5.1.5 Tiredness Effect

The course was designed to measure the effect of fatigue by having the first 3 firing posts being repeated at the end of the course. Figure 27 compares the shot groupings for each of these three positions across both treatments. Even though shot group sizes somewhat differ across the six combinations, there is no clear trend of there being a tiredness factor across all three targets.

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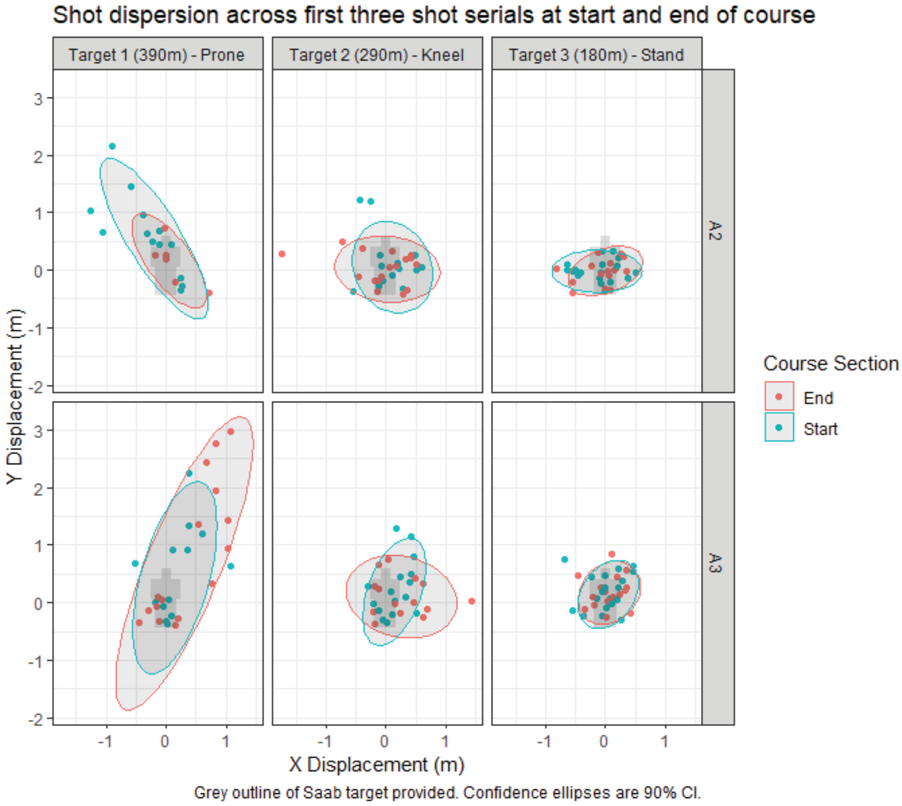

Figure 27 - Shot vector tiredness comparison (first 3 vs last 3 firing posts)

A summary of Figure 27 is provided by Table 6a and Table 6b, which present each combination's total number of hits and hit percentages. Table 6a shows that there was not a large difference in accuracy when fatigued. Table 6b gives an indication that firers were more accurate when fatigued at the end of the course. Overall, there appears to be a trend that participants were more accurate for the repeat of the same targets at the end of the course.

	A2	
Target	**Start**	**End**
1	3 (20%)	4 (22%)
2	7 (39%)	8 (40%)
3	10 (59%)	8 (47%)

(a)

	A3	
Target	**Start**	**End**
1	7 (23%)	7 (27%)
2	7 (24%)	13 (43%)
3	11 (39%)	14 (52%)

(b)

Table 6 - Hit percentages across first three and last three targets of SWEAT course

A Wilcoxon test was conducted to compare whether accuracy for end of course targets was better than at the start, using the hit percentage data of each firer. This gave a p-value >0.10, meaning that there was no significant difference in accuracy between the start and end of the course for these three targets. As follows:

```
        Wilcoxon signed rank test with continuity correction

data:  filter(wilcox_tired_shot, tired == "Start")$hit_per and
 filter(wilcox_tired_shot, tired == "End")$hit_per
V = 132.5, p-value = 0.156
alternative hypothesis: true location shift is greater than 0
```

The time to engage the first three and final three target posts was also evaluated to see whether there was a tradeoff to maintain accuracy. A boxplot of these results are presented in Figure 28. The prone position at the further range had a very large difference between the start and end of the course. Interestingly time to engage is much larger at the start when participants were not fatigued. This discrepancy is the underlying factor for why the overall time to engage at XL (Figure 26) is much larger for the A2 configurations than the A3 configuration. Otherwise, there does not seem to be a clear indicator that there is an overall fatigue effect on time to engage.

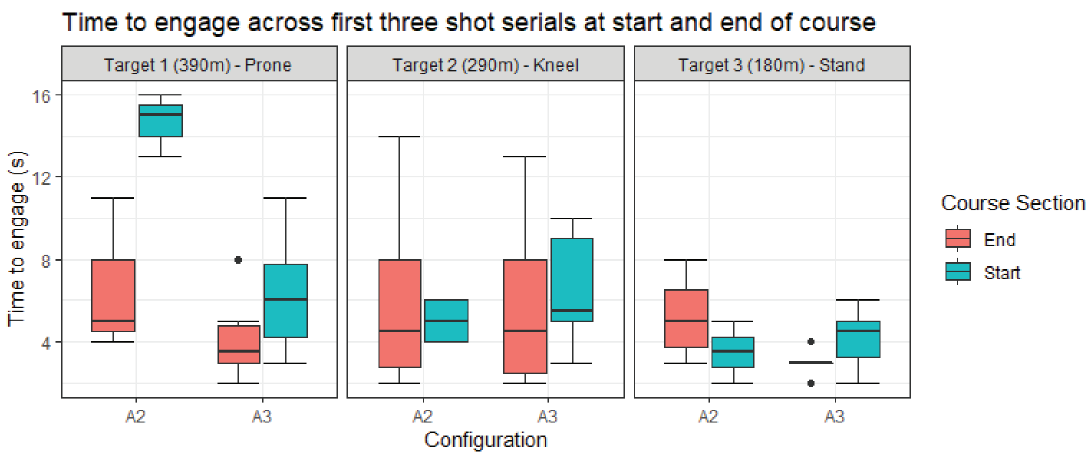

Figure 28 - Boxplot illustrating time to engage and tiredness comparison (first 3 vs last 3 firing posts)

5.2 Mobility Results

This section presents results from the timing data that was manually recorded by reviewing the GoPro video footage of each participant.

5.2.1 Course Completion Time

The time to complete the entire course was analysed first, with the results of those who completed the course for both treatments given in Figure 29 and Table 7.

Completion times ranged from 1,306 to 1,678 seconds (21m46s - 26m18s), with all participants running the course quicker for the A2 variant than for the A3 variant.

Due to the similarity in configurations used (Section 2.3), and all the A3 variants run on the first day with all of the A2 variants run on the second day, the differences shown are more indicative of a learning effect than participants' mobility being affected by the change in weapon configuration. A change in the experimental design would mitigate this.

Figure 29 - Time to complete entire course

Despite only having data for four firers, a Wilcoxon test showed that this difference was statistically significant at 90% confidence level, with a p-value of <0.10.

	Configuration	
Firer	A2	A3
1	-	1411
2	1618	1678
3	1336	1437
4	-	1547
5	1306	1512
6	1426	1582

```
        Wilcoxon signed rank exact test

data:  wilcox_course$A2 and wilcox_course$A3
V = 0, p-value = 0.0625
alternative hypothesis: true location shift is
 less than 0
```

Table 7 - Time to complete entire course for each participant

5.2.2 Obstacle Completion Time

In order to better identify the effects on each participant's mobility, a higher level of granularity than just total course time needs to be analysed. In Section 5.1.2, it was identified that there was a dependency between accuracy and course completion time as those who were more accurate fired less shots at firing stations.

Therefore, the time taken for each mobility obstacle was analysed across the four firers that completed both treatments. Their results are presented in Figure 30. Overall, each mobility obstacle was completed in a similar time across both configurations, however A2 serials completed the first obstacle (sprint 100 m) faster than the A3 serials. It is speculated that this was due to camera crews from the media being present on the second day, which likely encouraged participants to run faster. One of the range officers accompanying the participants did mention that they explicitly urged a couple of participants to slow down at this first obstacle.

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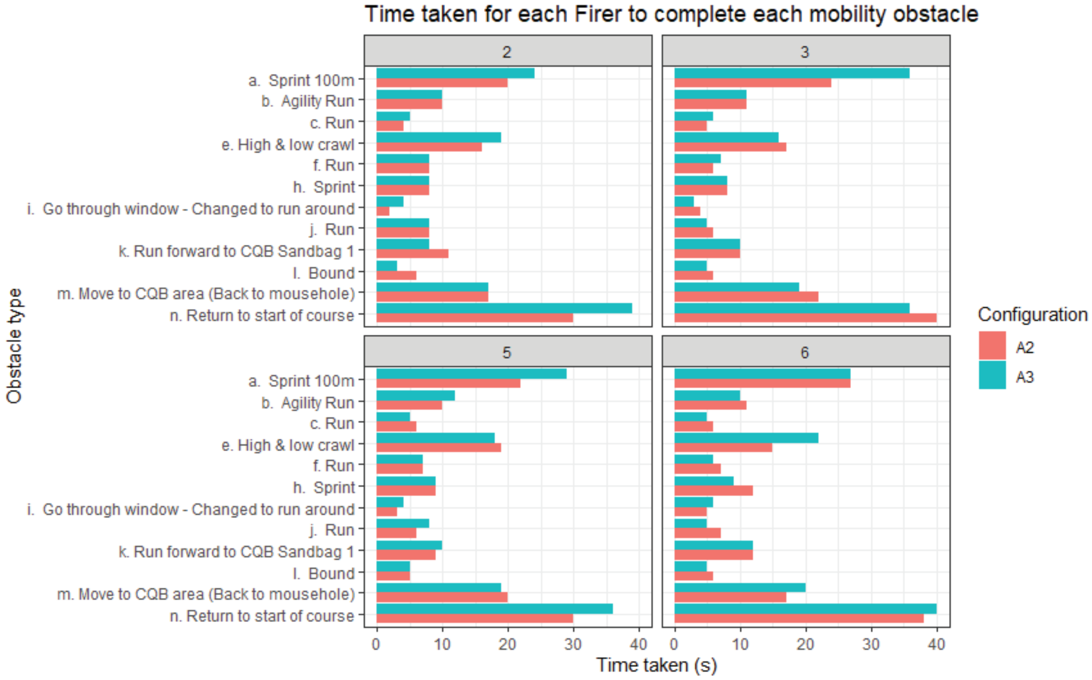

Figure 30 - Time to complete each mobility obstacle

A Wilcoxon test was conducted on this data and found that the difference in completion time across all mobility obstacles was not statistically significant between both treatments. This result is more impactful in denoting any effect on a participant's mobility across treatments as it only uses data when participants are doing mobility tasks. Obstacle completion times for all firers are numerically given in Table 10.

```
        Wilcoxon signed rank test with continuity correction

data:  wilcox_obstacles$A2 and wilcox_obstacles$A3
V = 250.5, p-value = 0.1437
alternative hypothesis: true location shift is less than 0
```

The cumulative time to complete all mobility is presented in Figure 31 and Table 8. These results ranged from 140 to 188 seconds (2m 20s - 3m 08s). The above Wilcoxon test was conducted on data from Figure 30 instead of Figure 31, as it has a sample size of 96 instead of 8.

	Configuration	
Firer	A2	A3
1	-	188
2	140	153
3	159	162
4	-	167
5	146	162
6	163	167

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Table 8 - Cumulative time (in seconds) to complete all mobility obstacles

Unlike in Figure 30, only half of those that ran both treatments showed a clear improvement in their mobility. This may still be as a result of the learning effect, however, it is more likely that it is due to the observer effect when camera crews were present to witness half of the A2 configuration runs. It is therefore important to have an experimental design that accounts for mitigating these factors (learning effects and external factors) in future trials.

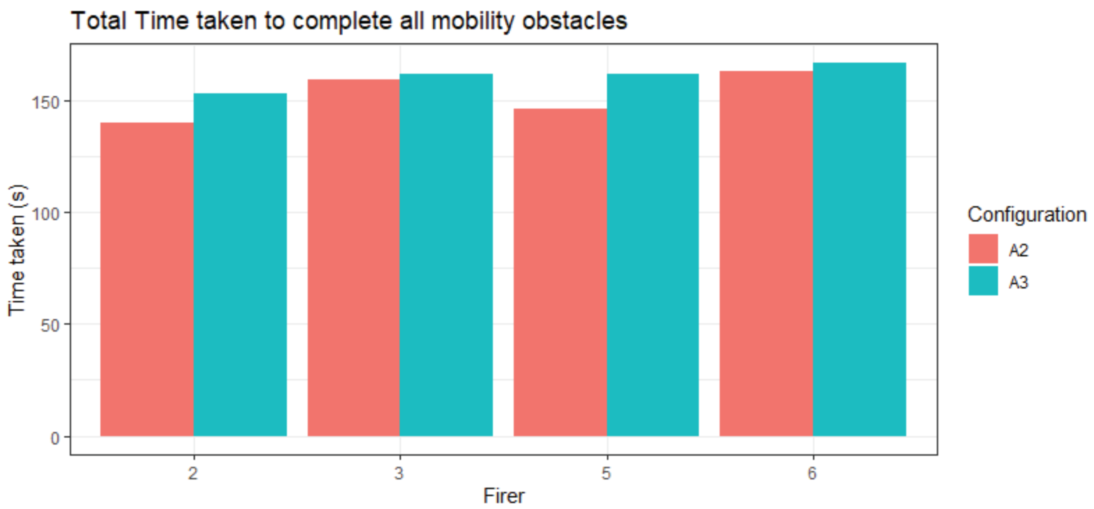

Figure 31 - Total Time to complete all mobility obstacles

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5.3 Questionnaire Results

The following section presents the results from the subjective evaluation questionnaire completed by participants following each run through of the course.

Note: All participants ran through the course with the SA80 L85 A3 on day 1, there may be some learning effects that have influenced the reporting for the SA80 L85 A2 assessed on day 2.

5.3.1 Question 1 - How well did you feel you could move through the course overall?

Figure 32 illustrates the participants' response. Overall, the participants felt that they could move well/very well through the course. Participant 6 did not make any comments on why there was a large difference between the SA80 L85 A2 and A3.

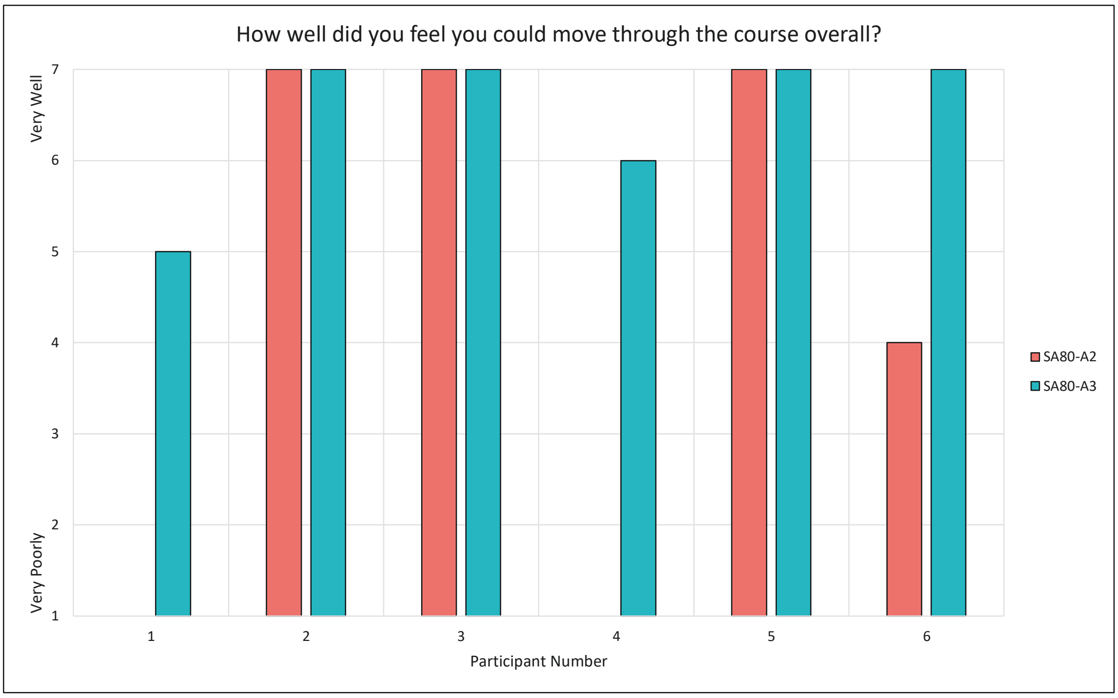

Figure 32 - How well did you feel you could move through the course overall?

No free text comments were received.

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5.3.2 Question 2 - How well could you establish a coherent sight picture with your weapon?

Figure 33 illustrates the participants' response.

The Elcan sight on both variants of the SA80 L85 was the same, located at the same position on the rifle, so this is unlikely to be the rationale for any variation in participants' response.

A comment was made about the long grass making it difficult in the prone position to sight the target. The issue of long grass was echo's by two participants as additional comments at the end of the questionnaire.

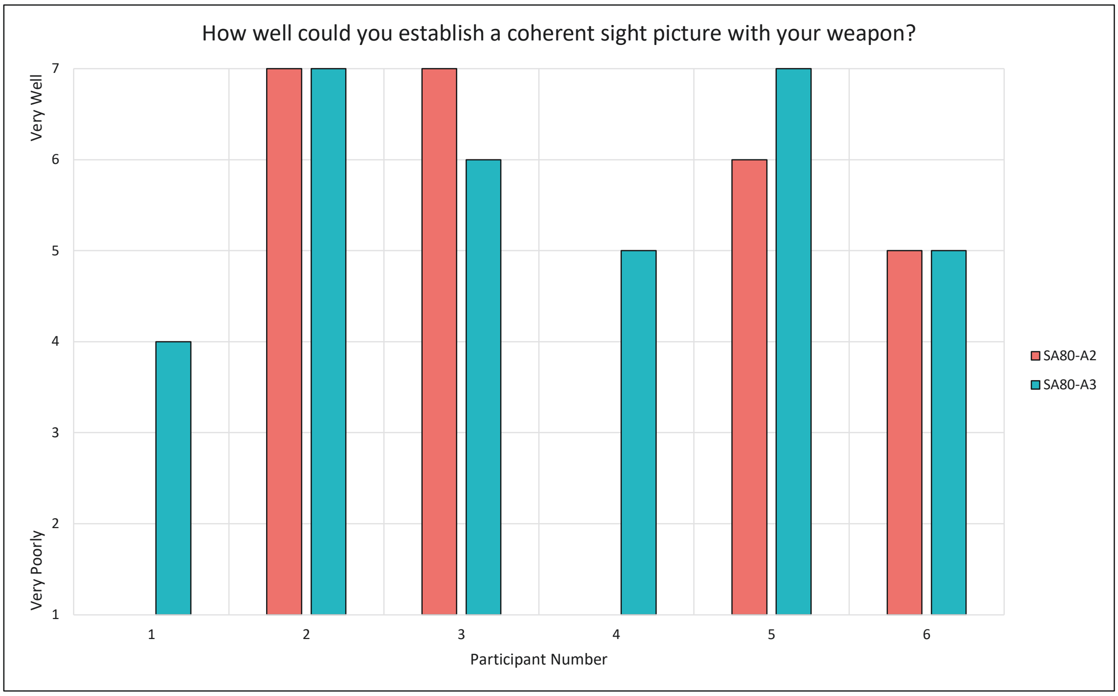

Figure 33 - How well could you establish a coherent sight picture with your weapon?

Free text comments were:

- *Long grass in prone made it more difficult, however in a 'real' situation you would make it work.*

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5.3.3 Question 3 - How well did you feel you could engage targets at long, medium and short ranges?

Figure 34 illustrates the participants' response.

All participants, for both SA80 L85 variants felt that they could engage the short range target very well.

For the medium range targets, participants provided a mixed response with no comments explaining their feelings. Generally, participants firing the SA80 L85 A3 felt that they could engage medium range targets the same or better compared to the SA80 L85 A2.

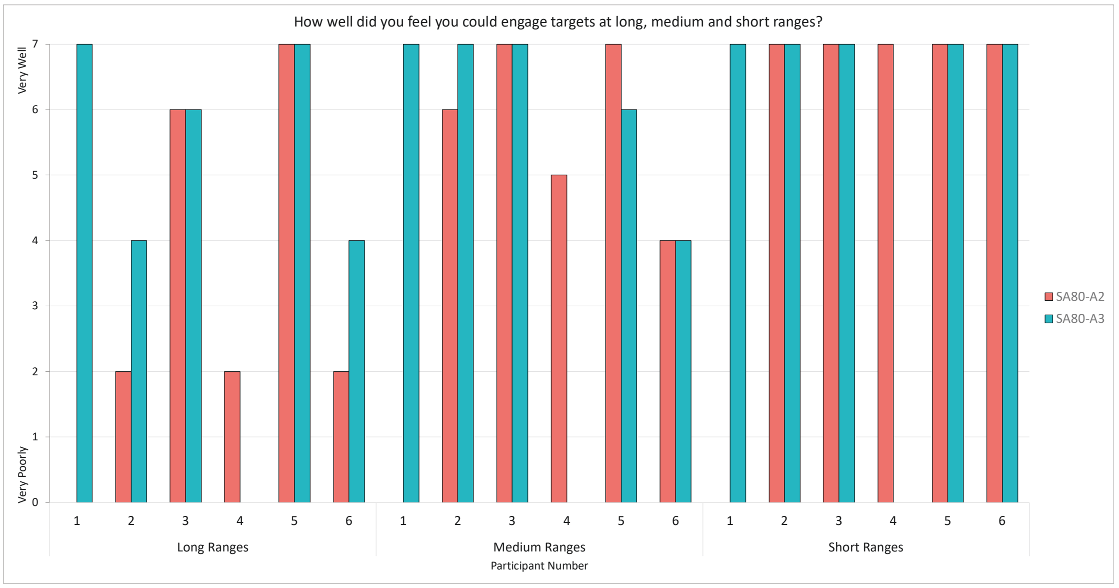

Figure 34 - How well did you feel you could engage targets at long, medium and short ranges?

No free text comments were received.

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5.3.4 Question 4 - Did you experience any issues with the following throughout the course?

Figure 35 illustrates the participants’ response.

Across the range of participants, 5 of the 6 reported at least one issues with aspects of the course.

Participants commented on the following issues:

- Firing in the prone position as the grass was too long;
- Firing on the move due to long grass and uneven ground;
- Some targets were too far to the left/right to maintain cover behind an obstacle whilst engaging;
- Carrying too many magazines for the VIRTUS pouches[11], or the magazine changes being difficult/slow;
- Participants were not familiar with firing from their weak side.

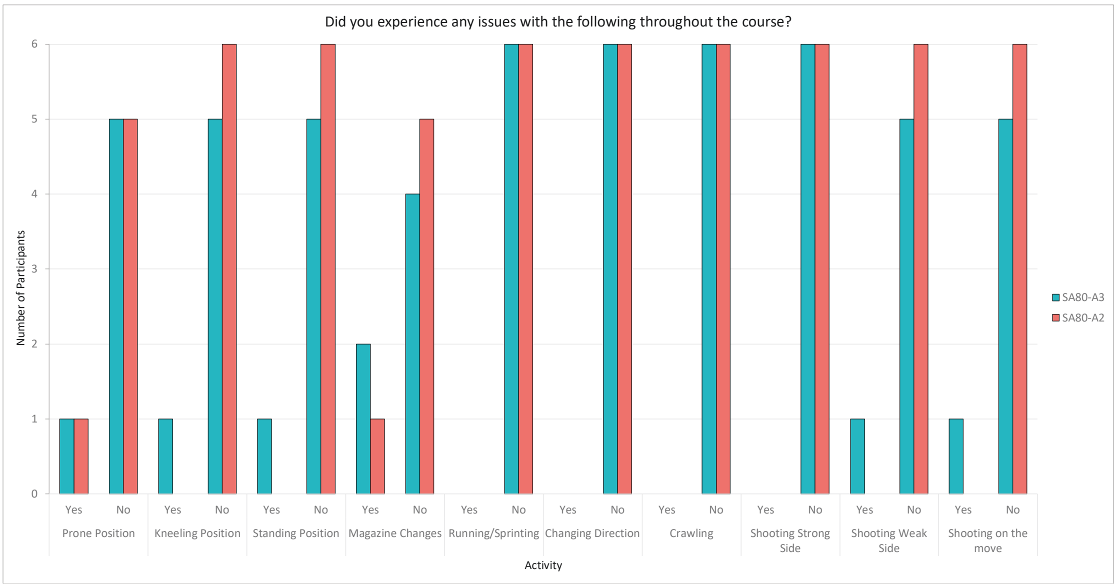

Figure 35 - Did you experience any issues with the following throughout the course?

Free text comments were:

- *Long grass (x4) [prone position].*
- *Carrying too many magazines for the VIRTUS webbing [magazine changes].*

[11] The VIRTUS magazine pouches were designed to accommodate the standard issue magazines. For the trial, the participants were issued with Magpul pouches that are slightly larger than the standard magazines.

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- *Harder to see targets [prone position].*
- *Some of the targets were too far over to maintain cover to engage [kneeling position].*
- *Uneven ground [running/sprinting].*
- *Due to VIRTUS equipment, it was slower and required more dexterity [magazine changes].*
- *Again due to firing at rapid whilst looking down the scope and trying to avoid long grass and uneven surface (especially hidden by the long grass) [shooting on the move]*
- *Not enough space to carry 6 magazines with VIRTUS webbings [magazine changes].*
- *We don't really fire from our weak side [shooting weak side].*

5.3.5 Question 5 - Please list likes, dislikes or changes/improvements you would make to the course.

Generally, the course was well received by the participants. They liked the variety of firing positions and ranges, and felt that it was a good challenge.

Participants disliked the number of magazine changes required, as well as the uneven ground and long grass that the course was set-up on (see Figure 36).

An additional comment was made that they would like to have practised drills for empty magazine stoppages. This is likely due to the inability to count rounds fired/left in each magazine, so the participants could not pre-empty magazine changes.

Free text comments were:

- Likes
    - *Firing from different positions, at different ranges.*
    - *Good idea for future equipment.*
    - *Well run course.*
    - *I think exactly what the British Army needs! 10/10.*
    - *Being able to go through the lane myself test in different positions and what works and doesn't.*
    - *Change to standard shoots that we do.*
    - *Plenty of different positions make it a good challenge.*

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  - *Overall run well.*
  - *Good facilities.*
- Dislikes
  - *Too many magazine changes.*
  - *Type of ground (long grass).*
- Changes/Improvements
  - *Practicing empty magazine stoppages (empty magazine).*

Figure 36 - Example of long grass and uneven ground

Following the completion of the trial, a semi-structured group wash-up with the participants was conducted. Their feedback was:

- **What were your favourite obstacles/firing points on the course?**
  - The troops liked the window because they were able to use it for support. Similarly, they liked the cover provided by the large obstacles as they enabled the troops to take realistic fire positions. They remarked that the monkey crawl into prone was a good transition. The fire on the move serial in the CQB section was especially well received.
- **What obstacles/firing points did you not like on the course?**
  - Any prone positions because the tall grass made it impossible to acquire the target. They had to adjust their position by leaning on sandbags which resulted in an uncomfortable position and a bent torso which made breath work difficult.

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- **Would this course be better or worse with different targetry?**
    - Whilst the troops liked the IMLF targets, they felt that the course would still be successful with different targetry;
    - The fall when hit set-up was preferable to the bob as it was more realistic. If possible moving left to right) targets were suggested by the troops. All the targets were in the same position, a large person, standing. Incorporating different size targets, such as huns heads (especially in the CQB) would provide an extra (and welcome) marksmanship challenge;
    - The soldiers would have liked multiple targets popping up at the same time but being instructed to only hit one (hostage targets).
- **Would sturdier obstacles improve the course?**
    - The troops did not feel the need for sturdier obstacles. They liked that the obstacles weren't very sturdy as the supports used in shooting aren't always to support the weight of the firer.
- **Do you think this is a good way to test equipment?**
    - The troops thought the course was challenging and representative, therefore a good way to test equipment. They stressed that the course was perfect for infanteers, therefore it may need to be adapted if being used with non-infantry soldiers.
- **Were you happy with the number of directing staff (DS) following you through the course (n=2)?**
    - Yes, two was appropriate and what they are used to. If more personnel were required to follow the soldier around the course it may be too crowded.
- **Other Comments**
    - The lack of time pressure was well received. They prefer the focus on marksmanship over speed and considered it more realistic;
    - The troops suggested that the course has potential beyond testing equipment, they even suggested it replace the Annual Combat Marksmanship Test (ACMT);
    - They would want to wear their daysacks when testing equipment;
    - There is opportunity to scale up the difficulty of the course by including serials such as a CASEVAC at the end of the course;

- This type of activity is not one troops get the opportunity to undertake often, so is of massive training benefit to them. If it were possible they would've liked more opportunities to receive feedback on their technique;
- The troops would like the opportunity to run the course individually, then in pairs, then as a fire team.

6 Conclusions

The UK pilot trial of the SWEAT course was successful, identifying a number of actionable recommendations and lessons learned that will be used by the NATO SAS-145 Panel and future iterations of the SWEAT course.

The pilot trial has verified that controlled LFTT is appropriate for assessing soldier performance as a function of varying equipment. Even with this pilot trial's low sample sizes (day 1 n=6, day 2 n=4), the data collected throughout the SWEAT course is sufficient to provide a variety of different metrics to determine differences in soldier lethality and mobility. With a higher participant count, it is anticipated that this course could be a great tool for comparing the operational effectiveness of different systems.

The NATO SAS-145 Panel will use the lessons learned from the UK pilot trial to inform and refine future iterations of the SWEAT course/method.

6.1 Lethality

The analysis on lethal effect proved to be successful, with the framework provided (Section 3.2) for data collection allowing effective data analysis on any differences across the two treatments tested. A variety of metrics (including hit percentages, shot group size and time to engage) could be drawn and illustrated effectively.

Due to the similarity in both treatments given (Section 0), there was not a significant difference between treatments, however, the effect of range was captured and is presented by Figure 37.

With more participants, this analysis piece could easily be extended to assess changes in lethality across each individual firing post.

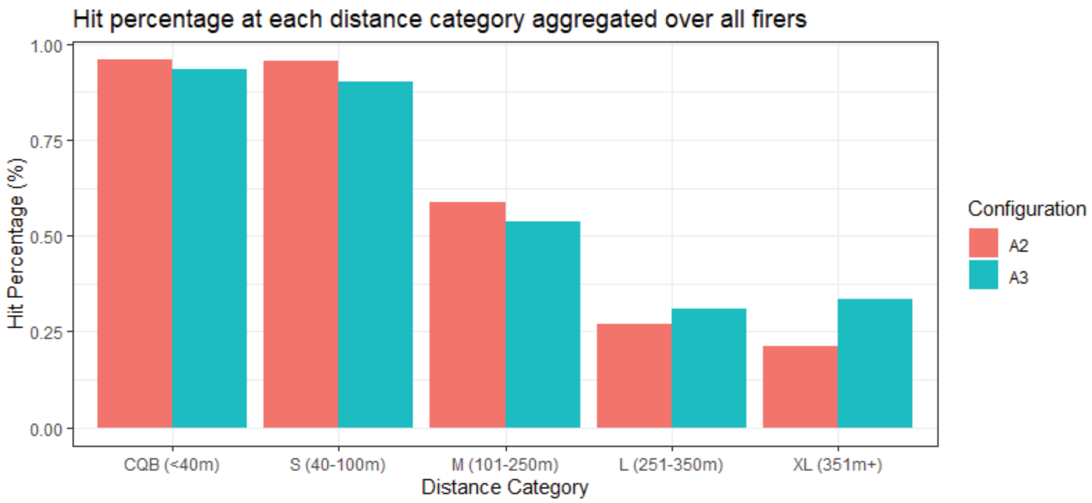

Figure 37 - Hit percentage between both treatments across each distance

Additionally, there was found to be no significant fatigue factor in both accuracy and time to engage. In fact, there was evidence to support participants spent longer to engage targets at the start of the course than at the end. Although it is speculated that this may be a learning effect as participants anticipate where targets will appear.

Further details on target analysis can be found in Section 5.1 and APPENDIX C.

6.2 Mobility

The analysis on mobility proved equally successful, with the framework provided (Figure 51) for data collection allowing effective data analysis across the two treatments tested.

Overall, for mobility, the results show there was a difference in total course completion time across treatments, however there was no significant difference in the cumulative time in completing mobility obstacles. Due to an experimental design that purposefully had all runs of a treatment on separate days, the significant difference found was likely as a result of both the participants and course instructors familiarising themselves with running through the course.

The course also has the potential to draw out the effect on mobility for specific obstacles of interest with a larger participant count. In this report, a mention is given to the initial 100 m sprint, where there were several factors that influenced participant completion time such as a learning effect, weather or a potential confidence boost due to the presence of media on that particular day.

Further details on timing analysis can be found in Section 5.2 and APPENDIX D.

6.3 Questionnaire

The questionnaires were administered to the participants successfully.

The subjective feedback of the SA80 L85 A2 compared to the A3 variant provided a mixture of results between the two variants.

As hypothesised in Section 0, the subjective feedback did not identify a clear preference between the two variants.

7 Recommendations

7.1 Participant Recommendations

As part of the subjective evaluation questionnaire participants provided suggestions for changes of improvements to the SWEAT course. These are as follows:

- Trial area needs to be on an even area with short grass;
- Magazines need to be compatible with the pouches being used;
- Some targets were located in areas that required leaving cover;
- Firing on the weak side was unfamiliar.

7.2 Course Organisers Recommendations

Following the after action review, the following recommendations were made by the Dstl SWEAT team:

- Smart targetry is required to semi-autonomously track firers/firing, reducing the potential for error and expediting data collection;
- Future experimental design should mitigate learning effects of the participants by splitting participants into two groups, one group trialling baseline equipment first, and the second group trialling the treatment first;
- DRDCs timing app can be used post trial while reviewing the video footage, but events occurred too quickly to use this live;
- A semi-automated method of raising the targets in the correct order is required as this will reduce;
- Translating the layout (Table 1) to the real layout was difficult. This would benefit from a visual layout map with distances from both the start position and the preceding obstacle;
- Flat ground with short grass is required, else timing will be affected;
- The use of an LRF would be useful for confirming target distance measurements and reduce error using the trundle wheel;
- A rationale and brief to the participants is required as to what each firing point/position is representing;
- Large capacity memory cards in the GoPro’s negates the need to transfer data after firing. 400 Gb memory cards were used and was able to capture footage of all serials in this pilot trial (n=10);

- The low wall and low window obstacles need to be sturdier to allow participants to climb over/through them. The sturdiness of remaining obstacles was adequate.
- Timestamps for obstacle completion could be automated with well-placed sensors, rather than having to manually review video footage.

7.3 Data Analyst Recommendations

Following the post-experimentation analysis, the following recommendations were made by the Dstl Data Analyst:

- The risk of missing data points is mitigated by a robust and efficient data collection and data identification method, with any data gaps backfilled;
- Multiple instrumented recording devices (in this trial the Saab Small Arms Transmitter and the Saab Instrumented Targets) provide timestamps allowing data to be cross-validated;
- The lethality data should include a tag that describes the firing position adopted and what obstacle was used as cover;
- An additional Extra Long (XL) distance tag needs to be included to distinguish between at targets ~300 m and ~400 m away;
- Five shots on each of the first three firing serials (and their repeats at the end) is recommended with a low participant count (<10). With more participants, this could be reduced to three shots each;
- Future experimental design should consider mitigating learning effects of the participants;
- Use paired data when possible (fix each result to a participant), which requires having the participants running through all treatments of the course;
- The data extracted from this course will yield better insights if it is used as a comparative tool between treatments, rather than for standalone use;
- A data analysis dashboard is integrated into the course design;
- The course could be reduced in size (and time) if required, with negligible effects to the overall data analysis if the following changes to the course design were made:
    - Reduce the number of magazine changes from five to two (~1 minute);
    - Remove firing point 8a (low wall, standing, medium range target) and 8b (low wall, standing, long range target) (~1 minute);
    - Remove firing point 11a (mouse hole, standing, short range target) and 11b (mouse hole, standing, medium range target) (~1 minute);

- The quality of comparison between weak and strong-side firing would strongly benefit from having the same target distances for firing points 4a/4b (low window, kneeling supported, right-hand side (RHS)) and their counterparts 6a/6b (low window, kneeling supported, left-hand side (LHS)). Likewise for the distances of firing positions 12a/12b (low window, kneeling supported, RHS) and 14a/14b (low window, kneeling supported, LHS).

- An optimised schedule is proposed for firing points 4, 6, 12 and 14:

  - 4. Kneeling, RHS of window: (a) M (b) L;
  - 6. Kneeling, LHS of window: (a) L (b) M;
  - 12. Kneeling, RHS of window: (a) M (b) S;
  - 14. Kneeling, LHS of window: (a) S (b) M.

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APPENDIX A Dimensions of Obstacles

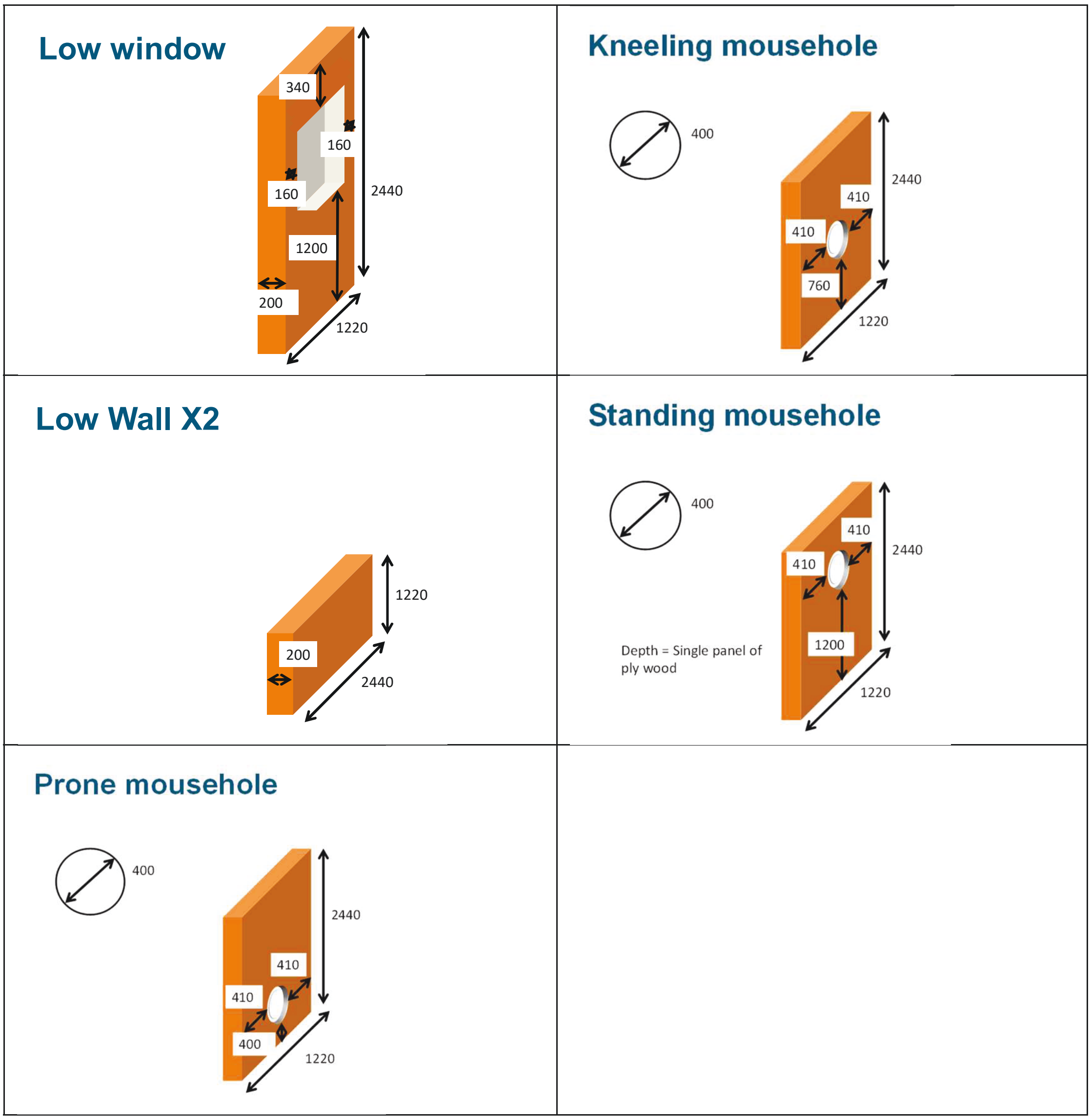

Figure 38 - Dimensions of obstacles (in mm)

APPENDIX B Trial Elements

1. **Obstacle 1: Sandbag**
   - 3 shots (bob on 1 and 2, fall on third)
     - Prone position
     - Long range target 1
   - Change magazine in the prone position

2. **Obstacle 1: Sandbag**
   - 3 shots (bob on 1 and 2, fall on third)
     - Kneeling position
     - Long range target 2
   - Change magazine in the kneeling position

3. **Obstacle 1: Sandbag**
   - 3 shots (bob on 1 and 2, fall on third)
     - Standing position
     - Medium range target 3
   - Change magazine to a full magazine in the standing position

a. **Move:**
   - Sprint 100m to Obstacle 2: Low Window

4. **Obstacle 2: Low Window**
   - a) 1 hit (up to 3 shots)
     - Kneeling to RHS of obstacle
     - Medium range target 5
   - b) 1 hit (up to 3 shots)
     - Kneeling to RHS of obstacle
     - Short range target 4

5. **Obstacle 2: Low Window**
   - a) 1 hit (up to 3 shots)
     - Supported position through window
     - Medium range target 2
   - b) 1 hit (up to 3 shots)
     - Supported position through window
     - Medium range target 3

6. **Obstacle 2: Low Window**
   - a) 1 hit (up to 3 shots)
     - Kneeling position LHS of obstacle
     - Medium range target 5
   - b) 1 hit (up to 3 shots)
     - Kneeling position LHS of obstacle
     - Long range target 1

b. **Move:**
   - Agility run for 20m weaving between 4 cones

7. **Obstacle 3: Mouse Hole Kneeling**
   - a) 1 hit (up to 3 shots)
     - Kneeling though mouse hole
     - Medium range target 3
   - b) 1 hit (up to 3 shots)
     - Kneeling though mouse hole
     - Long range target 1

c. **Move:**
   - Run 10m to obstacle 4: Low Wall

8. **Obstacle 4: Low Wall**
   - a) 1 hit (up to 3 shots)
     - Standing position (over wall)
     - Medium range target 5
   - b) 1 hit (up to 3 shots)
     - Standing position (over wall)
     - Long range target 1

d. **Move:**
   - High crawl for 10m, low crawl for 5m to Obstacle 5: Sandbag

9. **Obstacle 5: Sandbag**
   - a) 1 hit (up to 3 shots)
     - Prone position
     - Long range target 1
   - b) 1 hit (up to 3 shots)
     - Prone position
     - Medium range target 2

e. **Move:**
   - Run 10m to Obstacle 6: Mouse Hole Standing

10. **Obstacle 6: Mouse Hole Standing**
   - a) 1 hit (up to 3 shots)
     - Standing position (through mouse hole)
     - Short range target 3
   - b) 1 hit (up to 3 shots)
     - Standing position (through mouse hole)
     - Medium range target 4

11. **Obstacle 6: Mouse Hole Standing**
   - a) 1 hit (up to 3 shots)
     - Standing position RHS of Mouse Hole
     - Short range target 5
   - b) 1 hit (up to 3 shots)
     - Standing position RHS of Mouse Hole
     - Medium range target 2

f. **Move:**
   - Sprint 20m back to Obstacle 2: Low Window

12. Obstacle 2: Low Window

- a) 1 hit (up to 3 shots)
  - Kneeling to RHS of obstacle
  - Medium range target 2
- b) 1 hit (up to 3 shots)
  - Kneeling to RHS of obstacle
  - Short range target 5

13. Obstacle 2: Low Window

- a) 1 hit (up to 3 shots)
  - Standing unsupported position through window
  - Short range target 3
- b) 1 hit (up to 3 shots)
  - Standing unsupported position through window
  - Short range target 5

14. Obstacle 2: Low Window

- a) 1 hit (up to 3 shots)
  - Kneeling position LHS of obstacle
  - Medium range target 4
- b) 1 hit (up to 3 shots)
  - Kneeling position LHS of obstacle
  - Medium range target 2

g. Move:

- Run 5m to Obstacle 7: Sandbag

15. Obstacle 7: Sandbag

- a) 1 hit (up to 3 shots)
  - Kneeling position
  - Medium range target 2
- b) 1 hit (up to 3 shots)
  - Kneeling position
  - Short range target 3

h. Move:

- Run 10m to Obstacle 8: Mouse Hole Prone

16. Obstacle 8: Mouse Hole Prone

- 1 hit (up to 3 shots)
  - Prone position
  - Medium range target 4
- Change magazine

i. Move:

- To CQB area

17. CQB Sandbag 1:

- 2 rapid shots
  - Kneeling position
  - Short range target 3

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j. Move:
- o Bound to next sandbag

18. CQB Sandbag 2:
- o 2 rapid shots
  - Kneeling position
  - Short range target 3

k. Move:
- o Bound to next Sandbag 3

19. CQB Sandbag 3:
- o 2 rapid shots
  - Standing unsupported
  - CQB target 6
- o Change magazine

20. Move and Fire:
- o Walk and fire 5 shots to 5m line
  - CQB target 7

21. CQB No Cover:
- o Standing take 5 rapid shots
  - CQB target 8

l. Move:
- o Jog back to Obstacle 1

22. Obstacle 1: Sandbag
- o 3 shots (bob on 1 and 2, fall on third)
  - Prone position
  - Long range target 1
- o Change magazine in the prone position

23. Obstacle 1: Sandbag
- o 3 shots (bob on 1 and 2, fall on third)
  - Kneeling position
  - Long range target 2
- o Change magazine in the kneeling position

24. Obstacle 1: Sandbag
- o 3 shots (bob on 1 and 2, fall on third)
  - Standing position
  - Medium range target 3
- o Change magazine to a full magazine in the standing position

25. End of course

APPENDIX C Target Analysis

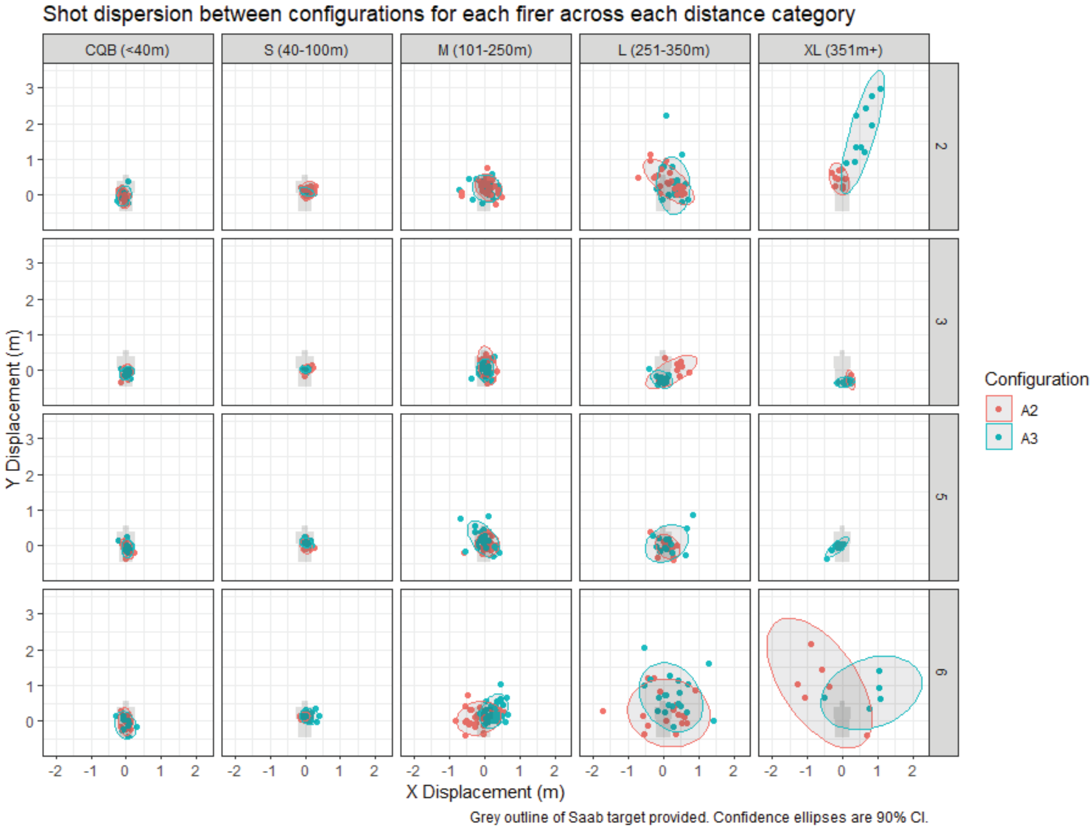

Figure 39 - Shot dispersion split across distance and firers

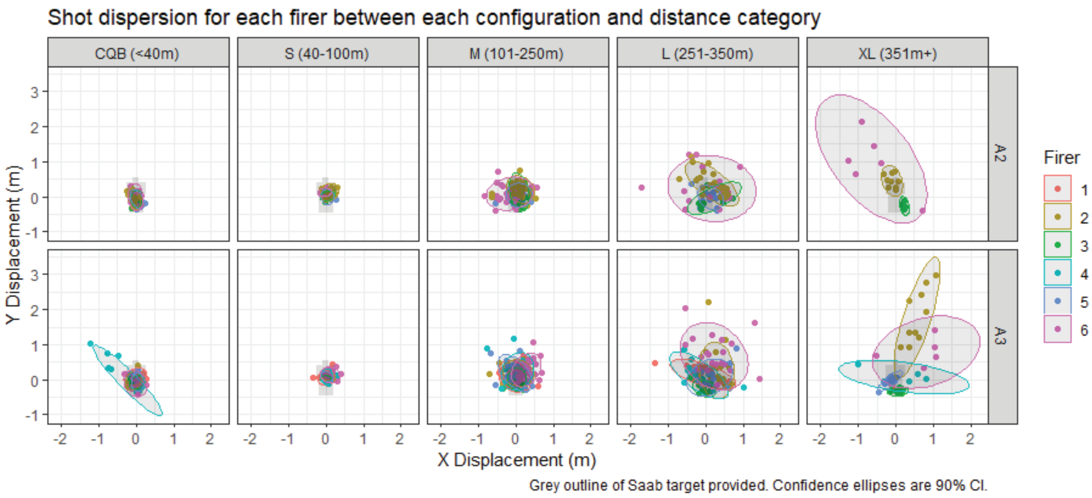

Figure 40 - Shot dispersion split across distance and configuration

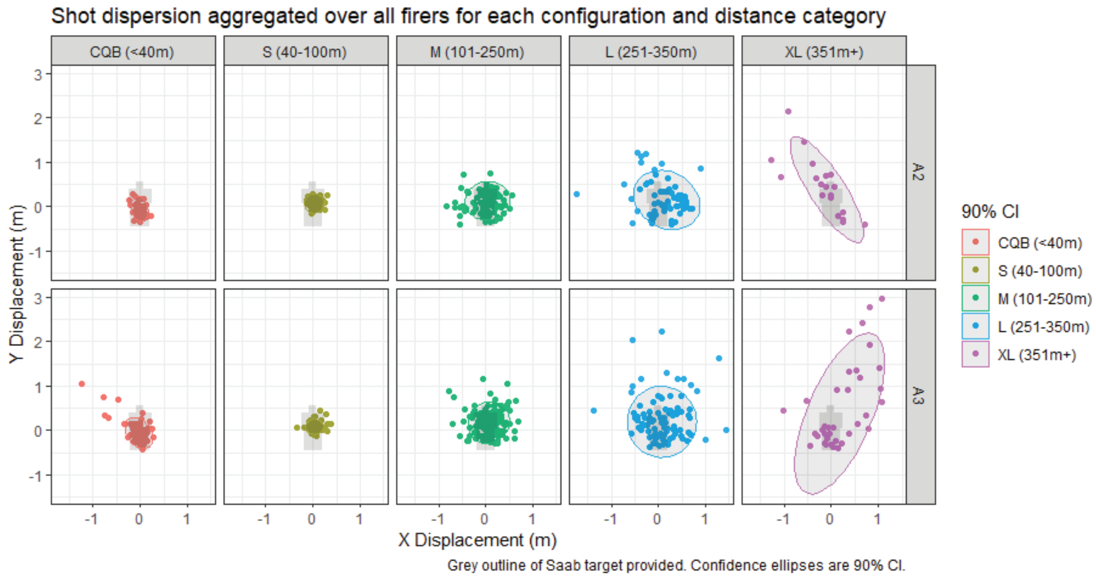

Figure 41 - Shot dispersion split across distance and configuration (aggregating all firers)

```
        Wilcoxon signed rank test with continuity correction

data:  wilcox_hit_percent$A2 and wilcox_hit_percent$A3
V = 57, p-value = 0.4008
alternative hypothesis: true location shift is greater than 0
```

Figure 42 - Wilcoxon Test result for difference in overall hit percentage between A2 and A3

```
        Wilcoxon signed rank test with continuity correction

data:  wilcox_hit_percent_close$A2 and wilcox_hit_percent_close$A3
V = 28, p-value = 0.2766
alternative hypothesis: true location shift is greater than 0
```

Figure 43 - Wilcoxon Test result for difference in hit percentage between A2 and A3 (only CQB/S/M)

```
        Wilcoxon signed rank test with continuity correction

data:  wilcox_hit_percent_far$A2 and wilcox_hit_percent_far$A3
V = 6, p-value = 0.3937
alternative hypothesis: true location shift is less than 0
```

Figure 44 - Wilcoxon Test result for difference in hit percentage between A2 and A3 (only L/XL)

Firer	Configuration	Tot_Miss	Tot_Hit	Tot_fired	Hit_percent	Tot_unregistered	Tot_registered
<fct>	<chr>	<int>	<int>	<int>	<dbl>	<int>	<int>
1	A3	32	42	74	56.8	11	63
2	A2	38	44	82	53.7	0	82
2	A3	39	40	79	50.6	1	78
3	A2	16	48	64	75	4	60
3	A3	8	55	63	87.3	5	58
4	A3	46	35	81	43.2	14	67
5	A2	23	46	69	66.7	12	57
5	A3	23	49	72	68.1	6	66
6	A2	47	35	82	42.7	8	74
6	A3	57	32	89	36.0	6	83

Table 9 - Overall hit percentage results of each Firer

Normality Testing:

The horizontal and vertical points of impact are represented in Figure 45 and Figure 46. In Figure 45 we can see that all of the graphs are symmetric, which means there is less sampling bias, but the CQB, S and M ranges have a high kurtosis (high peak). This peak is at zero which is the point of aim. Due to the peaks being 'skinny' (known as high kurtosis) it shows that the data is not normally distributed which means statistical metrics have less power. The CQB range having a high kurtosis is as a result of the firing on the move towards target. The S and M ranges having a high kurtosis is likely to be a consequence of aggregation of different firing positions (prone, kneeling and standing). With more people, it could be possible to separate out lethality data across firing positions within S and M.

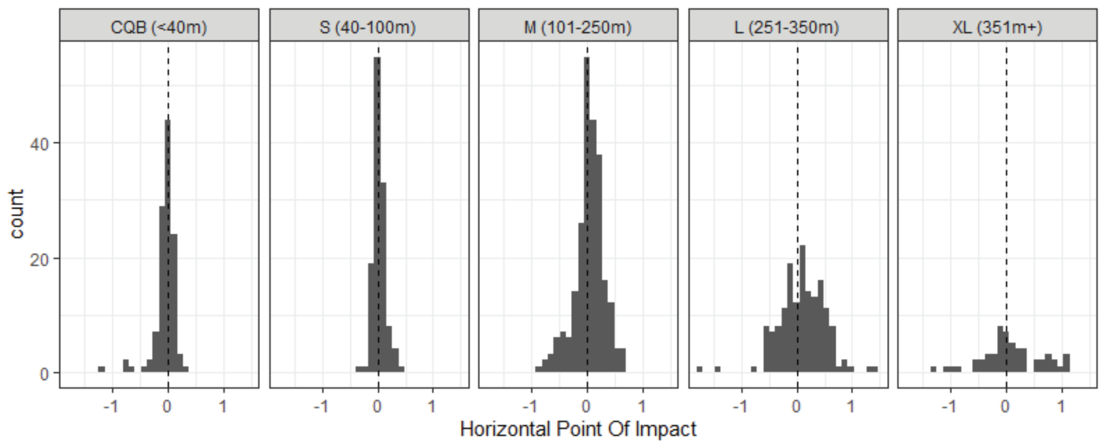

Figure 45 - Distribution curves of the horizontal point of impact across distances

Figure 46 shows that the vertical points of impact at each distance, except XL, look to be normally distributed. However, S, M and L ranges are not symmetric as the mean Point of Impact is above zero. The 'cut off' points tails off in positive direction but not the negative, due to be shots hitting the ground, and so below the target and not being registered by the target sensors. So the mean vertical PoI is biased for L and XL. Alternatively, this could be a result of firers aiming higher than the (0, 0) point, in other words the point of aim deviates upwards as distances increases.

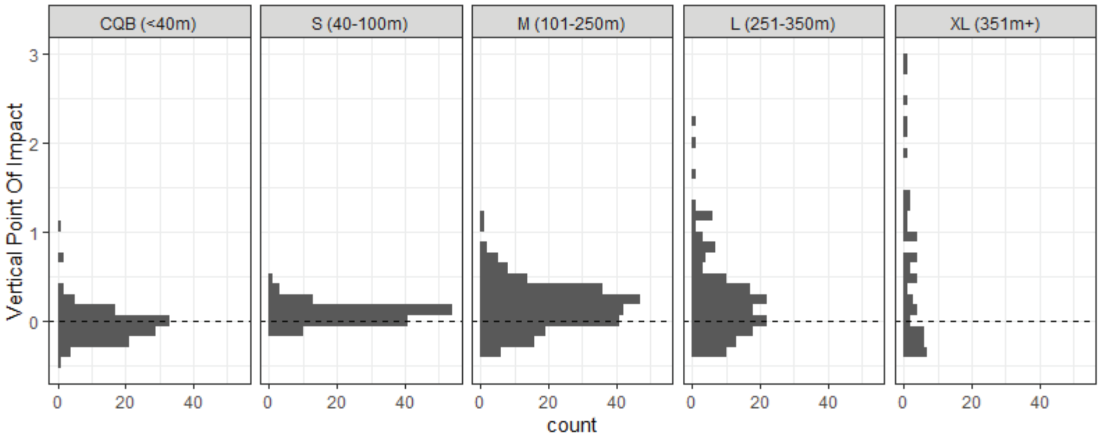

Figure 46 - Distribution curves of the vertical point of impact across distances

```
        Pairwise comparisons using Wilcoxon rank sum test with continuity correction

data:  friedman_dist_all$`Horizontal Point Of Impact` and friedman_dist_all$dist_cat

              CQB (<40m) S (40-100m) M (101-250m) L (251-350m)
S (40-100m)   0.00101    -           -            -
M (101-250m)  0.00015    0.67687     -            -
L (251-350m)  0.00093    0.36432     0.52790      -
XL (351m+)    0.52790    1.00000     1.00000      1.00000

P value adjustment method: holm
```

Figure 47 - Pairwise Wilcoxon testing for differences in horizontal MPI across distances

```
        Pairwise comparisons using Wilcoxon rank sum test with continuity correction

data:  friedman_dist_all$`Vertical Point Of Impact` and friedman_dist_all$dist_cat

              CQB (<40m) S (40-100m) M (101-250m) L (251-350m)
S (40-100m)   1.6e-09    -           -            -
M (101-250m)  4.5e-12    0.0047      -            -
L (251-350m)  6.6e-08    0.1191      0.6330       -
XL (351m+)    0.0011     0.1489      0.2776       0.4236

P value adjustment method: holm
```

Figure 48 - Pairwise Wilcoxon testing for differences in vertical MPI across distances

```
        Pairwise comparisons using Wilcoxon rank sum test with
 continuity correction

data:  filter(engage_df, Configuration == "A2")$time_to_engage
 and filter(engage_df, Configuration == "A2")$dist_cat

              CQB (<40m) S (40-100m) M (101-250m) L (251-350m)
S (40-100m)   0.0027     -           -            -
M (101-250m)  0.0004     0.0222      -            -
L (251-350m)  0.0004     9.3e-05     0.0222       -
XL (351m+)    0.0072     0.0027      0.0108       0.0864

P value adjustment method: holm
```

Figure 49 - Pairwise Wilcoxon testing for differences in time to engage across distances (A2)

```
        Pairwise comparisons using Wilcoxon rank sum test with
 continuity correction

data:  filter(engage_df, Configuration == "A3")$time_to_engage
 and filter(engage_df, Configuration == "A3")$dist_cat

             CQB (<40m) S (40-100m) M (101-250m) L (251-350m)
S (40-100m)  0.00021    -           -            -
M (101-250m) 3.6e-07    8.3e-05     -            -
L (251-350m) 9.2e-06    2.7e-05     0.02729      -
XL (351m+)   0.00024    0.00568     0.49256      0.50050

P value adjustment method: holm
```

Figure 50 - Pairwise Wilcoxon testing for differences in time to engage across distances (A3)

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APPENDIX D Timing Analysis

Obstacle (optionals highlighted)	Timestamp	Timestamp
1. Prone Supported - L	00:33	
1. Prone Supported - mag change	01:36	01:44
2. Kneeling unsupported - L		
2. Kneeling unsupported - mag change	02:39	02:46
3. Standing unsupported - M		
3. Standing unsupported - M mag change	03:38	03:51
a. Sprint 100m	03:57	04:24
4. Kneeling supported, side wall strong side - M; S		
5. Standing supported through (high) window - M; M		
6. Kneeling supported, side wall, weak side - M; L		
6. Kneeling supported, side wall, weak side - mag change	07:13	07:52
b. Agility Run	07:55	08:05
7. Kneeling mousehole - M; L (15cm x 15cm)		
c. Run	09:08	
d. Jump over low wall - Didn't jump just ran to low wall		09:13
8. Standing supported - M; L		
e. High & low crawl	10:52	11:14
9. Prone supported - L; M		
f. Run	12:11	
g. High wall - Changed to run to standing mousehole		12:17
10. Standing mousehole - S; M (20cm x 20xm)		
11. Strong side moushole wall standing - S; M		
h. Sprint	14:23	14:32
12. Kneeling strong side window - M; S		
13. Stranding unsupported through window - S; S		
14. Kneeling weak side window - M; M		
i. Go through window - Changed to run around	17:16	17:22
15. Kneeling unsupported - M; S		
j. Run	18:15	18:20
16. Prone mousehole - M (15cm x 15cm)		
16. Prone mousehole - mag change	18:51	18:59
k. Run forward to CQB Sandbag 1	19:00	19:12
17. Kneeling unsupported - S		
l. Bound	19:54	19:59
18. Kneeling unsupported - S		
m. Move to CQB area (Back to mousehole)	20:35	20:55
19. Standing unsupported - CQB		
19. Standing unsupported - CQB - mag change	21:26	21:36
20. Walking unsupported - CQB (5 shots)		
21. Standing unsupported - CQB		
n. Return to start of course	23:07	23:47
22. Prone Supported - L		
22. Prone Supported - L - mag change	24:32	24:41
23. Kneeling unsupported - L		
23. Kneeling unsupported - L - mag change	25:23	25:35
24. Standing unsupported - M		26:55

Reload and make weapon safe.
Took a long time as was talking with an instructor.

Went to wrong sandbag initially

Figure 51 - Data collection sheet used for recording mobility data

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	Configuration									
	A3						A2			
Obstacle	Firer 1	Firer 2	Firer 3	Firer 4	Firer 5	Firer 6	Firer 2	Firer 3	Firer 5	Firer 6
a. Sprint 100m	42	24	36	27	29	27	20	24	22	27
b. Agility Run	12	10	11	9	12	10	10	11	10	11
c. Run	7	5	6	5	5	5	4	5	6	6
e. High & low crawl	17	19	16	20	18	22	16	17	19	15
f. Run	6	8	7	9	7	6	8	6	7	7
h. Sprint	10	8	8	16	9	9	8	8	9	12
i. Go through window - Changed to run around	4	4	3	3	4	6	2	4	3	5
j. Run	7	8	5	6	8	5	8	6	6	7
k. Run forward to CQB Sandbag 1	10	8	10	10	10	12	11	10	9	12
l. Bound	6	3	5	4	5	5	6	6	5	6
m. Move to CQB area (Back to mousehole)	23	17	19	18	19	20	17	22	20	17
n. Return to start of course	44	39	36	40	36	40	30	40	30	38

Table 10 - Obstacle completion times for all firers across all obstacles and treatments

APPENDIX E Meteorological and Light Level Data

Date	Time	Condition	Reading
17/05/2022	0900	Light (Lux)	800
		Temperature (°C)	20
		Average Wind Speed (mph)	4
17/05/2022	1000	Light (Lux)	750
		Temperature (°C)	21
		Average Wind Speed (mph)	4
17/05/2022	1100	Light (Lux)	825
		Temperature (°C)	22
		Average Wind Speed (mph)	5
17/05/2022	1200	Light (Lux)	950
		Temperature (°C)	23
		Average Wind Speed (mph)	5
17/05/2022	1300	Light (Lux)	1075
		Temperature (°C)	No accurate measure available until next WBGT at 1400
		Average Wind Speed (mph)	7
17/05/2022	1400	Light (Lux)	850
		Temperature (°C)	23
		Average Wind Speed (mph)	4
17/05/2022	1500	Light (Lux)	1130
		Temperature (°C)	23
		Average Wind Speed (mph)	7
18/05/2022	0900	Light (Lux)	3000
		Temperature (°C)	16
		Average Wind Speed (mph)	2.5
18/05/2022	1000	Light (Lux)	875
		Temperature (°C)	16
		Average Wind Speed (mph)	1.5
18/05/2022	1100	Light (Lux)	2700
		Temperature (°C)	5.5
		Average Wind Speed (mph)	Range Ops did not provide data
18/05/2022	1200	Light (Lux)	3000
		Temperature (°C)	18.8
		Average Wind Speed (mph)	1

Table 11 - Meteorological and light level data

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APPENDIX F Participant Demographics

Day 1

Participant	DoB	Age	Height (cm)	Weight (kg)	Handedness	Phase 1	Phase 2	Rank	Tours	Experience of SA-80
1	20/06/1992	29	182	90	Left	Aug-16	Jan-17	L/Cpl	Op CABRIT 1, 6, 7	5
2	11/05/2003	19	183	81	Right	Sep-20	Aug-21	Rfn	-	1
3	21/11/1993	28	180	81	Right	-	-	L/Cpl	-	-
4	04/09/1992	29	182	75	Left	Oct-20	Jan-21	Rfn	-	1
5	22/04/1996	26	178	73	Right	Apr-19	Nov-19	L/Cpl	Estonia, Ukraine	4
6	09/05/2002	20	175	75	Right	Aug-20	Oct-20	Rfn	-	1.5
Average		25	180	79						3
SD		4.1	3.0	6.3						1.9
Min		19	175	73						1
Max		29	183	90						5

Day 2

Participant	DoB	Age	Height (cm)	Weight (kg)	Handedness	Phase 1	Phase 2	Rank	Tours	Experience of SA-80
2	11/05/2003	19	183	81	Right	Sep-20	Aug-21	Rfn	-	1
3	21/11/1993	28	180	81	Right	-	-	L/Cpl	-	-
5	22/04/1996	26	178	73	Right	Apr-19	Nov-19	L/Cpl	Estonia, Ukraine	4
6	09/05/2002	20	175	75	Right	Aug-20	Oct-20	Rfn	-	1.5
Average		23	179	78						2
SD		3.8	3.4	4.1						1.6
Min		19	175	73						1
Max		28	183	81						4

Table 12 - Participant demographics

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APPENDIX G Participant Questionnaire

Feedback on the Soldier Weapon and Equipment Assessment Tool (SWEAT) Course

Subjective Evaluation Questionnaire

Date	
Participant Number	
Equipment	

For all questions, as appropriate, answer by **circling a number** in the place which best describes your experience.

1. How well did you feel you could move through the course overall?

(Please circle a number)

Very poorly	1	2	3	4	5	6	7	Very well

Additional Comments

2. How well could you establish a coherent sight picture with your weapon?

(Please circle a number)

Very poorly	1	2	3	4	5	6	7	Very well

Additional Comments

3. How well did you feel you could you engage targets at long, medium and short ranges?

LONG RANGES

(Please circle a number)

Very poorly	1	2	3	4	5	6	7	Very well

MEDIUM RANGES

(Please circle a number)

Very poorly	1	2	3	4	5	6	7	Very well

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SHORT RANGES (Please circle a number)								
Very poorly	1	2	3	4	5	6	7	Very well
Additional Comments								

4. Did you experience any issues with the following throughout the course?			
	Yes	No	Comment
Prone Position			
Kneeling Position (supported/unsupported)			
Standing Position (supported/unsupported)			
Magazine Changes			
Running/Sprinting			
Changing Direction			
Crawling			

Shooting Strong Side			
Shooting Weak Side			
Shooting on the move			

5. Please list Likes, Dislikes or Changes/Improvements you would make to the course:		
Likes	Dislikes	Changes/Improvements

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APPENDIX H Participant Briefing

[dstl] The Science Inside

SWEAT - May 2022 Trial

Jon Russell – PTA DSS
WO1 Joe Dunn - MA

Ministry of Defence

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Brief

- ~1 hour
- Brief you on SWEAT
- What you'll need to do
- Kit
- Timing
- Questions
- Consent forms

2
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Background

- Soldier Weapon and Equipment Assessment Tool (SWEAT):
  - Developed under NATO SAS-145
  - To create a common NATO course designed to objectively measure and analyse the performance of the dismounted Soldier together with their weapon, equipment, ammunition and training
- Pilot study to validate the course and methodology in its entirety and will serve as the initial standard as to how this type of course may be run

3
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Aim

- Confirm the SWEAT methodology and evaluate the achievability of conducting all aspects of the procedure from the practicalities and administration of setting up the range, to data collection and data analysis.
- **Output:** A common NATO test methodology for assessing soldier weapons and equipment in the hands of the soldier
- **Exploitation:** Used to assess future soldier equipment

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What you will be asked to do

- Run through the course twice wearing (VIRTUS dress state 2)
  - 1x using your Iron Sight on the SA80A3
  - 1x using your Optic on the SA80A3
- 1 Questionnaire Completed after each run
  - To provide feedback on any benefits and issues with the course
- The course will take 15 minutes to run through each time. The task should be familiar to you as it is similar to the Individual Battle Skills Range (IBSR), but also includes elements of Live Fire Tactical Training (LFTT)
- You will use SA80A3 and L15A2 ammunition

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Video

- Video

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Questionnaire

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What data will we collect?

- Time – From start to finish, between each firing position and time of each shot, will be recorded using a stop watch (shot times will be recorded using a shot timer) – Shot fired, engagement and hit times.
  - Collected via video recording
- Shot location – x and y coordinates for each shot location will be recorded using acoustic sensors on the targets.
- Exposure – Cameras will be placed behind the shooting positions and post processing activity will determine the maximum area the soldier presented to the "enemy" behind each of the shooting positions.
- Subjective feedback – You will be asked to record their experience running the course in a short subjective evaluation questionnaire

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What will be do with the data?

- Overall hit percentage – Simple ratio of hits to misses from empirical data.
- Overall probability of Hit (PHit). PHit for given target size is modelled using a simple normal distribution calculation using azimuth (x) and elevation (y) errors, standard deviation. The potential limitations mentioned in 2.4.1.1.3 in D14 will be considered.
- Consistency Metrics (D50) – These are statistically robust metrics, closely linked to Circular Error Probable (CEP) and defined as D50: the diameter of a circle that will include 50% of the shots. CEP is the median radial deviation. The D50 is just two time the CEP.
- Accuracy metrics - Accuracy is the measurement of the distance from the Point of Aim (PoA) to the Mean Point of Impact (MPI).
- Significance Testing (e.g. T-Tests, Spearmans or Wilcoxon).

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[dstl] The Science Inside

The Course

Ministry of Defence

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10

Targetry

- 14 firing positions
- 36 individual shoots
- Ranges from ~400-5m
- 8 SAAB IMLF targets

The Course: Ranges

CQB: 0 – 20 m (3 shoots at this distance)

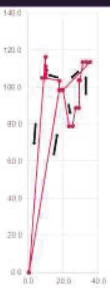
Short (S): >20 <100 m (9 shoots at this distance)

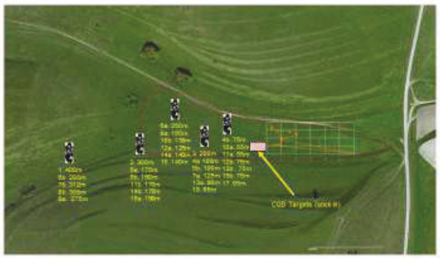
Medium (M): >100 <250m (16 shoots at this distance)

Long (L): >250m <500m (8 shoots at this distance)

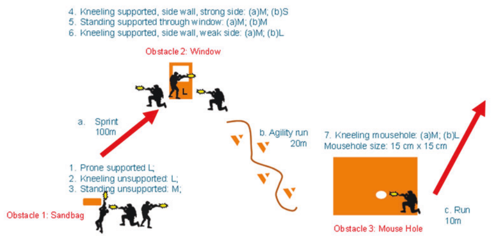
Course Size

Length:
116m x Width 35.3m

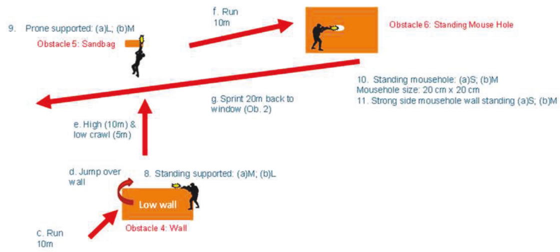




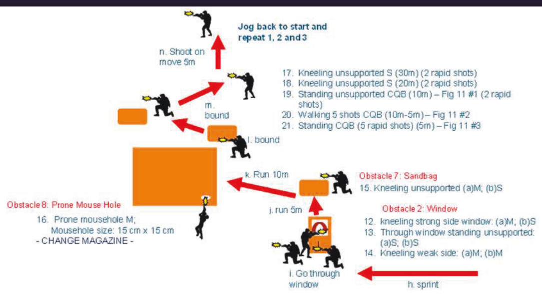
Part One



Part Two



Part Three



Admin

- 17-19 May 2022
- 0830-1700
- Box 6 SPTA
- Lunch
  - Any requirements?
- NATO attendees
- RSO – Sgt Sam Fisher, ITDU

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Figure 52 - Participant pre-brief

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APPENDIX I Participant Information Sheet

Study title: Solider Weapon and Equipment Assessment Tool (SWEAT) Course Methodology Study

MODREC Application No: 2092/MODREC/21

Invitation to take part:

Defence Science and Technology Laboratory (Dstl) are conducting a study on an obstacle course to assess equipment performance in the hands of the soldier.

You have been invited to take part as you are a dismounted close combat soldier. Before you decide if you want to take part, please take your time to read and consider the information in the next 3 pages and ask questions if anything is unclear.

What is the purpose of the research?

This study aims to establish a single method, which all NATO nations can use to test clothing, weapons and equipment using soldiers, and the effect these pieces of equipment and weapons have on lethality.

Who is doing this research?

The research is funded by the Ministry of Defence and is being conducted by Dstl as part of a NATO Science and Technology Project to develop a common method across NATO nations for testing soldier worn equipment and weaponry.

Do I have to take part?

No you do not; taking part is voluntary and you can withdraw at any time.

What will I be asked to do?

You will be asked to run through an obstacle course twice, wearing standard issue kit (VIRTUS dress state 2), during your normal work time. Your attendance is supported by your commanding officer and unit. The course will take 15 minutes to run through each time. The task should be familiar to you as it is similar to the Individual Battle Skills Range (IBSR), but also includes elements of Live Fire Tactical Training (LFTT) (See Figure 1).

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Figure 1: A comparison between IBSR Range (top two images) and an example SWEAT course set up in Canada in 2019 (bottom two images)

When you arrive you will be briefed on the study and safety procedures, and will be invited to fill in the consent form. You can ask any questions and withdraw from the study at any time. We will walk through the course altogether, going to each obstacle and explaining what you will need to do at each stage before you conduct any live fire.

When ready, you will be asked to run through the SWEAT course using your standard weapon iron sights and, firing at pop-up targets at each firing post. You will run from one obstacle to the next. You will take different firing positions and defeat targets at differing ranges each time. To begin with you will conduct a static shoot of targets in the prone kneeling and standing position. You will fire three rounds in each position, changing magazines between positions. After this you will have three attempts to defeat each target, before moving onto the next obstacle, targets will be set to fall when hit.

Once you have completed the course you will need to carry out a full unload and return to a central admin point to complete a post course questionnaire. You will then have a break and time to rest (more than an hour). You will then be asked to run through the same exact course again, this time using your standard issue Lightweight Day sight (LDS, a x4 optical sight).

Each time you go through the course you will be followed, at a safe distance, by a data collector from Dstl. They will measure the time you take to complete the course, as well as how long you take between obstacles and to defeat targets. Shot location data will also be recorded by the target control system. For the purpose of data collection, it is necessary for us to take images and video-recordings. These will be anonymised by blurring faces and any other identifiers (e.g. tattoos). These anonymised recordings will be used for analysis and may be included in the final report.

Please note, it is the course that we are assessing, not you.

What is the device or procedure that is being tested?

The trial is designed to test the SWEAT methodology and obstacle course design.

Are there any direct benefits to me of taking part?

There are no direct benefits of taking part.

What are the possible disadvantages (or risks) of taking part?

The risks are comparable to other LFTT range activities conducted by Dismounted Close Combat Soldiers. However, the range will be controlled by an experienced Range Conducting Officer (RCO) from the Infantry Trials and Development Unit (ITDU) to reduce any risks.

Data Protection

The legal basis for processing your personal data is a 'task in the public interest' and is for research purposes under GDPR and DPA 2018. For special category (images) your explicit consent is required. These conditions apply as long as we are applying appropriate protections to keep your personal data secure and safeguard your interests; these are set out in the MOD Privacy Notice and MOD Personal Information Charter. Data will be retained for a maximum of 7 years.

Can I withdraw from the research and what will happen if I withdraw?

Yes, you can withdraw at any time and can withdraw any data that has been provided up until that point.

Will I receive any expenses or payments?

You will receive £12.24 as part of the MoD Experimental Test Allowance (ETA). ETA is paid to Service personnel who voluntarily participate in officially-approved experimental tests as part of research studies in support of current and future frontline capabilities. ETA has been approved by your unit, and will be paid as part of your pay and is subject to tax and national insurance. [NB This may be subject to change depending on unit approval following the TERRF process].

Who do I contact if I have any questions?

Name: Jon Russell (Chief Investigator)

Address: Dstl Porton Down, Room 201, Bldg 005, Salisbury, Wiltshire, SP4 0JQ

Tel No: 01980 951404

E-mail: jdrussell@dstl.gov.uk

Who do I contact if I have a complaint?

Name: Stephen Smith (Group Leader, Land Platforms)

Address: Dstl Portsdown West, Portsdown Hill Road, Fareham, Hampshire, PO17 6AD

Tel No: 01980 951186

E-mail: SMSMITH@dstl.gov.uk

What happens if I suffer any harm?

If you suffer any harm as a direct result of taking part in this study, you can apply for compensation under the MOD's No-Fault Compensation Scheme.

Will my records be kept confidential?

All data produced from the research will be anonymised and kept in accordance with the Data Protection Act 2018, UK General Data Protection Regulation (GDPR) and the Dstl data protection policy.

Who has reviewed the study?

This study has been reviewed and given favourable opinion by the Ministry of Defence Research Ethics Committee (MODREC).

Compliance with the Declaration of Helsinki

This study will be conducted in accordance with the principles defined in the Declaration of Helsinki [12] as adopted at the 64th WMA General Assembly at Fortaleza, Brazil in October 2013.

[12] World Medical Association Declaration of Helsinki [revised October 2013]. Recommendations Guiding Medical Doctors in Biomedical Research Involving Human Subjects. 64th WMA General Assembly, Fortaleza (Brazil).

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APPENDIX J Consent Form for Participants in Research Studies

Title of Study: **Solider Weapon and Equipment Assessment Tool (SWEAT) Course Methodology Study**

MODREC Reference: 2092/MODREC/21

Please Initial or Tick Boxes

- **The nature, aims and risks of the research have been explained to me. I have read and understood the Participant Information Sheet and understand what is expected of me. All my questions have been answered fully to my satisfaction.** ☐
- **I understand that if I decide at any time during the research that I no longer wish to participate in this project, I can notify the researchers involved and be withdrawn from it immediately without having to give a reason. I also understand that I may be withdrawn from the study at any time by the research team. In neither case will this be held against me in subsequent dealings with the Ministry of Defence.** ☐
- **I consent to the capture of still images and video footage involving me.** ☐
- **I consent to the use of anonymised images involving me in the study report.** ☐
- **I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as confidential and handled in accordance with the provisions of the Data Protection Act 2018.** ☐
- **This consent is specific to the particular study described in the Participant Information Sheet and shall not be taken to imply my consent to participate in any subsequent study or deviation from that detailed here.** ☐
- **I understand that in the event of my sustaining injury, illness or death as a direct result of participating as a volunteer in**

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this research, I or my dependants may enter a claim with the Ministry of Defence for compensation under the provisions of the no-fault compensation scheme, details of which are attached. ☐

- **I agree to participate in this study** ☐

Participant's Statement :

I ....

agree that the research project named above has been explained to me to my satisfaction, and I agree to take part in the study.

Signed : Date :

Investigator's Statement :

I ....

confirm that I have carefully explained the nature, demands and any foreseeable risks of the proposed research to the Participant.

Signed : Date :

Contact Details of Chief Investigator :
Name: Jon Russell

Address: Dstl Porton Down, Room 201, Bldg 005, Salisbury, Wiltshire, SP4 0JQ

Tel No: 01980 951404

E-mail: jdrussell@dstl.gov.uk

Contact Details of Volunteer Advocate

Name: Stephen Smith

Address: Dstl Portsdown West, Portsdown Hill Road, Fareham, Hampshire, PO17 6AD.

Tel No: 01980 951186

E-mail: SMSMITH@dstl.gov.uk

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APPENDIX K Arrangements for the Payment of No-Fault Compensation to Participants in MoDREC Approved Studies[13]

1. The MoD maintains the 'No Fault Compensation Scheme' specifically for the payment of no-fault compensation to, or in respect of, a volunteer who suffers illness and/or personal injury as a direct result of participating in research conducted on behalf of the MoD. The no-fault compensation arrangements apply to research participants (Military, Civilian, or non-MoD) who take part in a trial that has been approved by the MoD Research Ethics Committee.

2. A research participant wishing to seek no-fault compensation under these arrangements should contact the Directorate of Judicial Engagement Policy, Common Law Claims and Policy (DJEP-CLCP), Ministry of Defence, Level 1, Spine 3, Zone J, Whitehall, London, SW1A 2HB who may need to ask the Claimant to be seen by a MoD medical adviser.

3. CLCP will consider reasonable requests for reimbursement of legal or other expenses incurred by research participants in relation to pursuing their claim (eg. private medical advice, clinical tests, legal advice on the level of compensation offered) provided that they have been notified of the Claimant's intention to make such a claim.

4. If an injury is sufficiently serious to warrant an internal MoD inquiry, any settlement may be delayed at the request of the research participant until the outcome is known and made available to the participant in order to inform his or her decision about whether to accept no-fault compensation or proceed with a common law claim. An interim payment pending any inquiry outcome may be made in cases of special need. It is the Claimant's responsibility to do all that they reasonably can to mitigate their loss.

5. In order to claim compensation under these no-fault arrangements, a research participant must have sustained an illness and/or personal injury as a direct result of participation in a trial/study approved by MoDREC. A claim must be submitted within 3 years of when the incident giving rise to the claim occurred, or, if symptoms develop at a later stage, within 3 years of such symptoms being medically documented.

6. The fact that a research participant has been formally warned of possible injurious effects of the trial upon which a claim is subsequently based does not remove MoD's responsibility for payment of no-fault compensation. The level of compensation offered shall be determined by taking account of the level of compensation that a court would have awarded for the same injury, illness or death had it resulted from the Department's negligence.

7. In assessing the level of compensation, CLCP, in line with common law principles, will take into account the degree to which the Claimant may have been responsible for his or her injury or illness and a deduction may be made for contributory negligence accordingly.

[13] Section agreed with DJEP-CLCP Dep Hd 28/10/13.

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8. In the event of CLCP and the injured party being unable to reach a mutually acceptable decision about compensation, the claim will be presented for arbitration to a nominated Queen's Counsel. CLCP will undertake to accept the outcome of any such arbitration. This does not affect in any way the rights of the injured party to withdraw from the negotiation and pursue his or her case as a common law claim through the Courts.

Additional/Alternative Compensation Arrangements

9. **Compensation for Service Personnel.** Service personnel who took part in studies before 06 April 2005 and who consider that they may have suffered later harm or disability due to that study should contact MoD Defence Business Services-Veterans (DBS-Vets), Service Personnel and Veterans Agency (SPVA) for consideration of a war disablement pension. The personnel who are entitled to make claims under the war disablement pension scheme are laid out on the SPVA website,[14] as are details of the claim's process.

10. In the event of service personnel suffering injury or disability as a result of their participation in MoDREC approved MoD research on or after 06 April 2005 then they may be entitled to compensation under the Armed Forces Compensations Scheme (AFCS). The details of the AFCS are promulgated on the MoD Intranet,[15,16] and are also available on the DBS-Vets website.[17] Claims should be made to DBS-Vets following the instructions available on the MoD Intranet and DBS-Vets website.

11. In the event of service personnel suffering injury or disability as a result of their participation in MoDREC approved MoD research which is sufficiently serious for subsequent medical discharge from the services, their medical records will automatically be forwarded to DBS-Vets for consideration of compensation and pension enhancements [18] in addition to whatever MoD pension/gratuity they are already entitled to by virtue of their service. Similarly, in the event of death as a result of their participation in MoDREC endorsed MoD research, their dependants may be entitled to receive a supplemented pension.

12. However, if either a Service person or their dependants receive payment under the MoD 'no fault compensation' arrangements (or as the result of a common law compensation claim) for the same condition as that for which a pension is received, any pension entitlement may be reduced since compensation should not be paid twice for the same injury, disability or death.

13. **Civilian Pensions.** In the event of a civilian research participant suffering injury or disability as a result of their participation in MoDREC endorsed MoD research sufficiently

[14] http://www.veterans-uk.info/pensions/wdp_new_index.html
[15] DIN http://defenceintranet.diif.r.mil.uk/libraries/corporate/DINS%20Archive/2008/01102RestrictDINs.pdf
[16] Armed Forces Compensation Scheme - Statement of Policy. http://defenceintranet.diif.r.mil.uk/libraries/library1/DINSJSPS/20110714.1/974_AFCS_Statement%20of%20policy4.pdf
[17] http://www.veterans-uk.info/pensions/afcs_new.html
[18] http://www.veterans-uk.info/pensions/med_discharge.html

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serious for them to subsequently suffer a loss in earnings capacity; they may be eligible for benefits under Section 11 of the Principal Civil Service Pension Scheme (PCSPS). Further details are available in the PCSPS booklet Injury at Work. Similarly, in the event of death as a result of participation in MoDREC approved MoD research, their dependants may be entitled to receive benefits.

14. **Common Law Compensation.** If a research participant or their representative believes that injury, disability or death was caused by the negligence of the MoD or its staff, and do not wish to pursue the possibility of a 'no-fault' compensation payment, a common law claim for compensation should be submitted to Directorate of Judicial Engagement Policy, Common Law Claims & Policy (DJEP-CLCP) (at the address in Para 2 above) detailing the full facts of the claim and stating that common law compensation is being sought.

Multinational/Multicentre Research and Research Involving Other Government Departments

15. When MoDREC is involved in studies which involve Departments other than the MoD there may be a requirement for specific Compensation Arrangements on a study by study basis.

APPENDIX L Consent Form for Video, Audio and Photography

Purpose

Dstl (The Defence Science and Technology Laboratory) records individuals for training, recruitment and promotional purposes under the data protection legal basis of consent, for its internal and external (social media) channels.

I (the signee) consent to the capture of still images, video footage and/or audio recordings involving me, hereafter referred to as "recordings".

I agree that the recordings may be published in a variety of formats and media types including, but not limited to printed promotional materials, social media campaigns, podcasts, promotional videos, live streams and newspapers/magazines. Recordings will be stored securely on Dstl's restricted network, under the ownership of the communications function, but may be visible to Dstl staff.

I grant Dstl a licence to use the recordings for up to 5 years from the date on this form. I understand I have no claim of ownership of the recordings and that I will not receive remunerations now, nor in the future. All recordings are owned by Dstl under Crown copyright.

I permit the recordings to be shared with the Ministry of Defence (MOD). I understand that before the recordings can be shared with any other third party, my permission will be sought using the contact information I provide.

I understand I can withdraw consent and request that the recordings be erased and no longer used, but they may still appear in material already published. Please contact Dstl Data Protection for more information.

For more information about your rights please refer to the Information Commissioner's Office: www.ico.org.uk.

Retention

Dstl is fully aware of the requirement that care be taken not to put personal security at risk. Data on this form will be processed by Dstl together with obtained recordings. We may share data on this form with enforcement agencies if required by law. Dstl is an executive agency of the Ministry of Defence (MOD). Please refer to the MOD's privacy notice for more details.

Recording Details (administrative use only)	
Date	.
Description (e.g. recording location, event name, job number)	

Subject Details		
Forename(s)	**Surname**	**Email**
Staff Number (If Dstl)	**Division (If Dstl)**	**Organisation**

Recording Usage	
Internal (e.g. Dstl and MOD)	
External (e.g. NATO)	

Subject Signature	
Signature	

References

[1] NATO D/14 Handbook. Evaluation Procedures for Future NATO Small Arms Weapon Systems. 2018.

[2] NATO STANAG 4513. Incapacitation and Suppression. 2004.

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[4] Close Combat – Ranges. Operational Shooting Policy. Volume 1 – Personal Weapons. 2019.

[5] DE&S. User Assembly, Care and Maintenance Instructions. AESP 8470-B010-201. Version 1.3. July 2018.

[6] JSP 539. Governance of Research Involving Human Participants. Version 3.3. May 2021.

[7] Ministry of Defence Research Ethics Committee. Favourable Opinion Letter. 2092/MODREC/21. 8 March 2022.

[8] MODREC Application Form. Soldier Weapon and Equipment Assessment Tool (SWEAT) Course Mythology Study. 2092/MODREC/21. Version 1.4. 8 March 2022.

List of abbreviations

AAR	After Action Review
ACMT	Annual Combat Marksmanship Test
CASEVAC	Casualty Evacuation
CE	Confidence Ellipse
CEP	Circular Error Probable
CQB	Close Quarters Battle
CAEP	Combat Arms Ear Plugs
Dstl	Defence Science and Technology Laboratory
DRDC	Defence Research and Development Canada
DS	Directing Staff
IW	Individual Weapon
ITDU	Infantry Trials and Development Unit
IR	Infra-Red
IMLF	Instrumented Metricised Live Fire
LCGDSS	Land Capability Group Dismounted Soldier System
LCpl	Lance Corporal
LRF	Laser Range Finder
LDS	Lightweight Day Sight
LFTT	Live Fire Tactical Training
LEAP	Load Effects Assessment Programme
LHS	Left-Hand Side
LOMAH	Location of Miss and Hit
MANOVA	Multivariate Analysis of Variance
MODREC	MOD Research Ethics Committee
OS	Ordnance Survey

OSP	Operational Shooting Policy
PIS	Participant Information Sheet
PCS	Personal Clothing System
PDD	Personal Detection Device
PHit	Probability of Hit
RHS	Right-Hand Side
RCO	Range Conducting Officer
Rfn	Rifleman
DAN	Saab Data Acquisition Network
SIT	Saab Instrumented Target
SPTA	Salisbury Plain Training Area
STV	Scalable Tactical Vest
SD	Secure Digital
SAT	Small Arms Transmitter
SWEAT	Soldier Weapon and Equipment Assessment Tool
SD	Standard Deviation
STANREC	Standardised Recommendation
SAS	Systems Analysis and Studies
TES	Tactical Engagement Simulation
ToE	Team of Experts
TMH	Trigger Mechanism Housing
UBACS	Under Body Armour Combat Shirt
UGL	Underslung Grenade Launcher
W&S	Weapons and Sensors
WTS	Wireless Target System
XL	Extra Long

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14. Abstract

The SAS-145 Research Task Group (RTG) explored the requirement to develop a standardized approach to assessing the impact of Soldier, weapon and equipment factors on Soldier Combat Effectiveness and Efficiency (SCEE). Three primary factors were identified as main contributors to SCEE: Soldier lethality, mobility, and survivability. While each of these factors is often examined in isolation, they are rarely examined in concert, resulting in difficulties to assess trade-offs and interdependencies between factors. To bridge this gap, the RTG developed a standardized Soldier-in-the-loop assessment course that would allow Soldier lethality, mobility, and survivability to be examined simultaneously. The resulting Soldier, Weapon and Equipment Assessment Tool (SWEAT) is an operationally relevant, live-fire obstacle course designed to assess the three main contributors to SCEE simultaneously in a standardized manner that can be used across NATO nations to achieve consistency in test standards. The recommendations provide standard definitions and equipment for measurements of lethality, mobility, and survivability, and recommended course of fire. Planning and processing tools are also embedded in the recommendations to allow for adjustments based on range specifications and system being assessed. The ultimate recommendation is that this integrated course be incorporated into a STANREC for distribution across NATO nations.

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