



Taser 10 Technical Testing Results

Addendum: Spear Design Comparison

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PA Consulting was asked by the Home Office to produce an independent technical report on the Axon Taser 10 (T10) conducted energy device (CED). This document is an addendum to a previous report (*MIQ-24-0014-D - Taser 10 Technical Testing Results*) and contains technical analysis of additional testing focussing on a new spear design, which was conducted by specialists Ribbands Explosives at their licensed site in Norfolk, based on Home Office guidance and methodologies used in the previous report. These results are one of several reports that will inform the Home Office's assessment of the suitability of the T10, including its relative performance to previous models of Tasers.

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Executive summary

PA Consulting was asked by the Home Office to produce an independent technical report comparing the performance of different spear designs for the Axon Taser 10 (T10), which is supplemental to previous testing (report *MIQ-24-0014-D - Taser 10 Technical Testing Results*). The results are one of several inputs to the Home Office's assessment of the suitability of the T10. The testing compared two spear designs (denoted 'Old' and 'New') using skin simulant and skull simulant targets, and assessed the probes' kinetic behaviour, including accuracy and key ballistic parameters.

Skin penetration was similar between the two designs with highly repeatable penetration and retention, differing only by a 20% deeper average penetration by the New design

For both spear designs, 100% of shots: penetrated the skin simulant target (which is intended to simulate highly vulnerable areas of skin); caused perforation of the outer layer (from entry of the impact absorber); and were retained in the target. On average, the New design penetrated 4.1mm deeper (20% more) than the Old design, resulting in the probe body entering the skin for 47% of shots compared to 0% for the Old design. Whether the amount of extra penetration makes a practical or operational impact is outside the scope of this report.

Skull penetration testing showed highly similar performance of the two designs aside from a higher rate of pin prick marks on the bone from the Old design

No shots for either spear design caused penetration or fracturing of the skull models; all shots scored a 1 on the Dstl fracture scale. The rate of bounce-outs was highly similar (32-35%) for both spear designs, and there were no clearly significant differences in how the spears deformed upon impacting the bone. The main difference in behaviour was that the Old design left pin-prick marks on the bone in 80% of shots, compared to 55% for the New design. This is likely due to the Old design having a more acute tip angle, which may create marks more easily even with similar or lower kinetic energy at the bone (noting that the Old design was observed to penetrate less deep than the New design in the skin penetration testing).

Accuracy of both spears was highly comparable with no statistically significant differences and similar results to previous data, aside from two potentially anomalous velocity measurements for the New design

The accuracy of the two designs was highly similar at three tested ranges (3.0m, 10.1m and 13.4m), within the limits of statistical significance possible by the number of shots. Similarly, measurements of the mass, velocity, momentum and kinetic energy of the Old and New probes were highly comparable, with no significant differences identified on average. There were, however, two outlier velocity measurements at 9.625m range that were 20-37% higher than the average velocity, corresponding to a 45-90% higher kinetic energy of 7.38-9.71J. It is possible that these are artefacts of the measurement system, but there is no direct evidence to confirm that these are erroneous, so are included in the analysis and should be considered as potential extreme cases without further evidence.

Data for the Old spear design was broadly similar to previous testing data, with some differences believed to be due to a combination of hardware/software revisions and environmental conditions

Broadly, the data in this report for the Old spear design was highly similar to previous data taken using the same spear design. The main differences were a slightly reduced skin penetration depth (by 3% on average), no occurrences of skull fracture or penetration (compared to 5% of shots observed to cause this previously), and slight differences in accuracy (most apparent at 10.1m). The causes are hypothesised to be a combination of environmental conditions (the ambient temperature was approximately 2°C lower due to using a different test range to accommodate the required testing timescales, which could, for example, increase the hardness of the skin simulant models), manufacturing variation in the targets (particularly the

skull models) and changes to the hardware and software (the details of which were not available to the authors of this report).

Overall, the Old and New spear designs broadly behave highly similarly, with some differences that should be considered alongside other evidence.

Both spear designs overall displayed very similar performance across skin penetration, skull penetration and accuracy testing. The main differences were that the New design demonstrated a 20% deeper skin penetration depth while also showing a reduced likelihood to cause marks on bone in skull penetration testing. Note also that the data in this report used clamped devices, and the previous testing identified that hand-fired devices appear to exhibit a small (2.5%) decrease in average velocity and an increase in the velocity spread, compared to clamped device; the results in this report therefore represent a worst-case scenario when considering the injury-causing potential of devices.

1 Introduction

The purpose of this report is to present the results of testing of different spear designs (see Section 1.3) for the Taser 10 (T10) conducted energy device (CED), which were performed in accordance with a Technical Test Plan¹ developed based on Home Office guidance. The results are intended to supplement the results of previous testing,² specifically to provide information on the performance of a newly available spear design relative to the previously tested design, and to be a key input into the Home Office's assessment of the suitability of the T10.

The testing was conducted by Ribbands Explosives at their licensed firearms and explosives site in Norfolk.

1.1 Document structure

Three separate tests were conducted as part of the T10 spear comparison testing, and these are reported in turn in the main body of the report with a brief methodology (using methodologies from previous testing), presentation of key data, and analysis of the conclusions. This is supported by more details in appendices, where appropriate, and the raw testing data is provided in Appendix A.

This report is structured as follows:

- **Chapter 1: Introduction**
A summary of the purpose of the report.
- **Chapter 2: Skin penetration**
Assessment of any differences in the risk of skin penetration between the different spear designs using a skin simulant target.
- **Chapter 3: Skull fracture/penetration**
Assessment of any differences in the risk of skull fracture or penetration between the different spear designs using a skull fracture model target.
- **Chapter 4: Kinetics: Accuracy**
Assessment of the impact of the different spear designs on the accuracy of the T10 and its ability to achieve reliable probe placement at three different ranges.
- **Chapter 5: Other**
Brief description of an unusual result during testing that was excluded from the analysis and appears to be a quality control issue.
- **Appendices**
Additional detail on the testing including:
 - **Raw testing data** (Appendix A).
 - **Additional detail on methodologies, equipment lists and results**, sorted by the type of testing (Appendix B to Appendix D).

1.2 Definitions

For reference throughout this report, the key constituent parts of a Taser CED are defined as:

- **Handle / Body / Weapon** – the bulk of the Taser system into which the magazine and battery pack are inserted.
- **Battery pack** – inserted into the handle and charged in the battery dock.

¹ Report MIQ-25-0026-D - Technical Test Plan - Barb Comparison

² Report MIQ-24-0014-D - Taser 10 Technical Testing Results

- **Magazine** – inserted into the handle of the T10, containing cartridge bays (the X2 does not have a magazine; individual twin-probe cartridges are inserted directly into the weapon).
- **Bay / Cartridge bay** – contained in the magazine; house cartridges (referred to as ‘barrels’ in the original Home Office guidance).
- **Cartridge / Ammunition** – inserted into a bay in the T10 magazine, or directly into the X2. The two main types of cartridges are ‘duty’ (also referred to as ‘live’ or ‘operational’) and ‘HALT’ (short for hook-and-loop training), used for operational use and training use respectively.
- **Probe / Projectile** – contained within each cartridge; travels towards the target while either spooling out wire behind it (T10), or drawing wire from the fixed cartridge (X2). More details on the constituent parts of the T10 and X2 Duty probes are provided in Section 2.2.
- **Wire** – enables an electrical pathway between the energy-generating circuit in the weapon, and the probe; deployed as the probe travels forward.
- **Central information display (CID)** – the display on the rear of the handle that provides information to the operator about the status of the device (inc. the number of loaded bays).
- **Connection** – as defined by Axon, a connection specifically refers to a valid electrical pathway between two probes.
- **Spear / Dart** – the metal shaft on the end of the probe that is intended to penetrate and remain in a target, incorporating hooks/barbs to aid retention.

Note that, throughout this report, any reference to skin means the skin simulants, and any reference to skull or bone means the skull simulant.

1.3 Context

The reason for this additional testing was the introduction of a new spear design by Axon for the T10. For previous testing,³ the only spear design available was the ‘Old’ design; subsequently a ‘New’ design was issued by Axon. The designs differ in their shape and manufacturing – the New design has multiple barbs compared to a single barb on the Old design, and the New design is manufactured by laser-cutting to create a rectangular cross-section, whereas the Old design manufacturing process produced a cylindrical cross-section. Figure 1 shows the different designs, noting that the rest of the projectile (including its total length) is understood to be unchanged. Axon claim that the revised design reduces manufacturing variability and improves retention in a target across multiple angles of engagement.⁴

³ Report MIQ-24-0014-D - Taser 10 Technical Testing Results

⁴ TASER 10 Cartridge: LASER-Cut Spear Improvements.

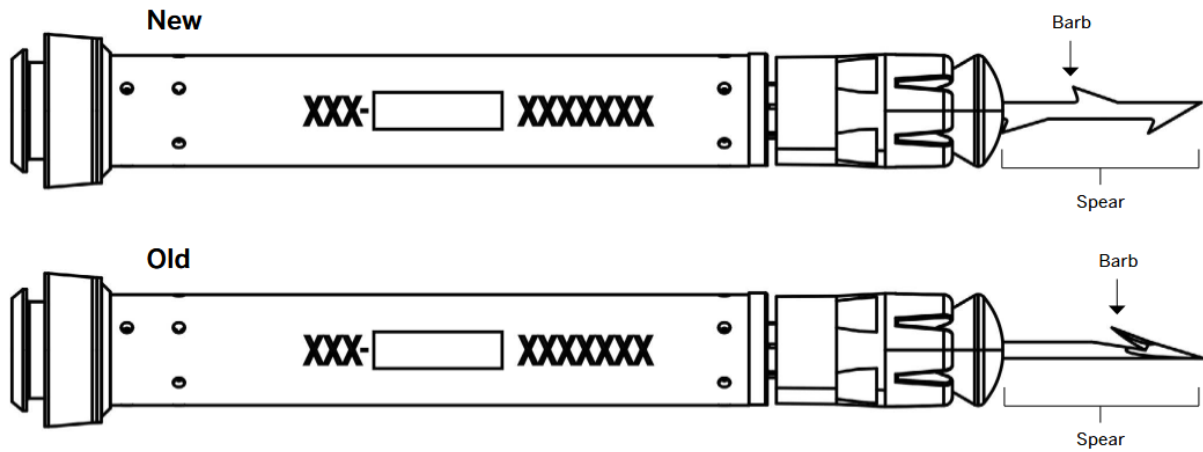


Figure 1: A comparison of the New and Old spear designs. Top: diagram from Axon documentation.⁵ Middle: Photograph taken during testing with the Old design on the left and New design on the right. Bottom: Photograph taken during testing with the Old design on the top and the New design on the bottom. Note that the photographs are of probes previously fired into a target as part of accuracy testing, with the spears subsequently straightened out manually, which is the result of any slight misalignments of the spears or impact absorbers.

⁵ TASER 10 Cartridge: LASER-Cut Spear Improvements.

2 Skin penetration

2.1 Purpose

This test assessed the effect of the different spear designs on the risk of skin penetration by the probe body from 'contact range' (meaning as close as is reasonably practical for testing).

2.2 Methodology

The target was a TP5 skin simulant pack (provided by Dstl) designed to simulate particularly vulnerable areas of human skin. The skin simulant was mounted vertically and a probe was fired at the target from a range of 50cm, then visual inspection of the target was performed to assess the extent of skin penetration, with one or more photographs taken to document the penetration. The target was moved before the next shot was fired. This was repeated 30 times for both the Old and New designs (for a total of 60 shots). As an additional comparison, 8 shots were fired at a single skin simulant target, alternating between Old and New spear designs in order to remove any potential variations between different skin simulants or time-varying environmental conditions.

The result of each shot was noted based on:

1. If any penetration of the probe observed.
2. If so, how much of the probe penetrated the target, with the T10 probe divided up into the spear, the probe body, and the rubber impact absorber. Measurements of the probe penetration depth were estimated by measuring the protruding length and subtracting that from the known total 61mm length of an undamaged probe. When measuring the protruding length, if the probe was hanging down or loose, and/or there was a visible empty hole where it had clearly penetrated, the measurement would be taken after reinserting using very light pressure; the difference this made was only 1-2mm. The accuracy of the protruding and penetrated lengths is ± 2 mm.
 - We define here the term '*perforation*' as referring to any breakage of the outer layer of the skin simulant by part of the probe other than the spear (for the purposes of the skin penetration testing). This distinguishes the scenario of severe lateral movement/tearing of the outer skin layer(s) from the more common scenario of penetration of the thin spear into the skin causing minimal lateral movement/tearing of the skin.
3. If the probe remained in the target.

For reference, the T10 probes with the Old and New designs of spear are shown in Figure 1. A T10 probe consists of:

- a 11mm spear (a shaft protruding from the probe body, with a barb)
- a 13mm impact absorber (comprised of two rubber elements, coloured white and black)
- a 37mm probe body, with a brass ring on one end of the body that connects to the impact absorber

The total length of a T10 probe is 61mm.

2.3 Results

Table 1 summarises the results of the skin penetration testing for the Old and New spear designs, with full results in Appendix B.

Testing		Number of shots	Effect on target				Penetrated length (mm)			
			% shots penetrated target	% shots remaining in target	% shots where impact absorber perforated target	% shots where probe body perforated target	Mean	Standard deviation	Minimum	Maximum
Previous Testing	Old Spear Design	15	100%	93%	93%	53%	23.4	4.5	16	30
Current Testing	Old Spear Design	34	100%	100%	100%	0%	22.6	1.7	19	25
	New Spear Design	34	100%	100%	100%	47%	26.7	2.0	24	31

Table 1: A summary of the skin penetration results for the Old and New designs. For each shot, the occurrence of various effects (spear penetration, impact absorber penetration, probe body penetration, and the probe remaining in the target) are denoted by the dark shaded areas. The remaining exposed length of the probe was recorded, and the penetrated length inferred from the exposed length and the known total length of the probe (61mm).

All shots with both spear designs penetrated the target, were retained in the target, and resulted in at least the impact absorber penetrating the target as well as the spear, resulting in perforation of the outer skin layer. This is highly similar to the previous testing (that used the old spear design) in which just one out of the 15 shots did not perform the same (that shot bounced out of the target).

The performance of the designs differed in the depth of penetration – the Old design penetrated 22.6mm on average, and never resulted in the probe body entering the skin, whereas the New design penetrated 26.7mm on average (20% deeper) and the probe body entered the skin on 47% of shots. This difference is statistically significant given that the difference in penetration depth (4.1mm on average) is significantly larger than the standard deviation of the measurements (1.7-2.0mm). It is hypothesised that this difference (in the absence of a significant change in the kinetic energy – see Section 4.3.4) could be due to the two barbs on the New design helping to generate lateral movement of the skin away from the axis of the probe, which may help slightly enlarge the hole and reduce the energy required for the impact absorber to perforate the skin (which would result in more kinetic energy left to increase the penetration depth).

Interestingly, the performance of the New design is similar to the performance of the Old design in the previous testing, which had a 53% rate of the probe body entering the skin, substantially higher than the 0% rate for the Old design in the spear comparison testing. One potential cause of this performance discrepancy of the Old design is the ambient temperature (due to using a different test range to accommodate the required testing timelines) – in the previous testing it was 19.0°C compared to ~17°C for the spear comparison testing. It is hypothesised that the cooler temperature for the spear comparison testing resulted in an increase in the hardness of the skin simulant that was sufficient to slightly reduce the penetrative ability of the Old design (noting that the average depth of penetration reduced by 0.8mm – a 3% decrease).

Alternatively, the different hardware or software revisions (see Section 4.2) could be the source of the discrepancy.

Regardless of the differences in the behaviour of the Old design, the testing allows a good comparison between the two spear designs in the same conditions (i.e. the same hardware/software revisions and environmental conditions – including 8 shots into a single skin simulant target at the end of testing that alternated between New and Old designs to minimise any variation between different targets or varying environmental conditions), and shows that the New design penetrates the skin 20% further on average with similar variability (based on very similar standard deviations) to the Old Design, while both designs offer the same retention performance within the testing conducted. Note that the skin simulant used is intended to replicate particularly vulnerable areas so it is conceivable that for less vulnerable skin the retention of the probes in the target may differ between the Old and New design, but there was not evidence for this within the methodology of the testing conducted.

2.4 Conclusions

Both spear designs showed consistent penetration and retention in the skin simulant target, as well as perforation by the impact absorber. The New design penetrated further into the skin by 4.1mm on average (20% deeper) than the Old design, resulting in the probe body entering the skin for 47% of shots for the New design compared to 0% for the Old design. The New design therefore has been shown to penetrate deeper than the Old design for the skin simulant targets used (which are intended to simulate highly vulnerable areas of skin). Whether the amount of extra penetration makes a practical or operational impact is outside the scope of this report.

The performance of the Old design was observed to differ between the spear comparison testing and previous testing, with slightly reduced penetration (by 3% on average) that meant the rate that the probe body entered the skin went from 53% to 0%. This is hypothesised to be due to a slightly different hardness of the skin target based on a 2°C difference in ambient temperature, or could be due to differences in the revisions of the hardware and software used.

Note also that the data in this chapter used clamped devices, and it has been previously identified that hand-fired devices appear to exhibit a small (2.5%) decrease in average velocity and an increase in the velocity spread, compared to clamped devices (see previous testing⁶). The results in this chapter therefore represent a worst-case scenario when considering the injury-causing potential of devices.

⁶ Report MIQ-24-0014-D - Taser 10 Technical Testing Results

3 Skull fracture/penetration

3.1 Purpose

This test was to assess any differences in the risk of skull fracture or penetration between the Old and New spear designs by using a skull fracture model target.

3.2 Methodology

A T10 was fired at short range (50cm – the practical limit for testing, and for consistency with other tests) into bone surrogate models provided by Dstl (the same type as used for skull penetration previous testing). Three to four T10 shots were used on each model with no evidence of any influence of previous shots on subsequent shots.

The model was visually inspected by the operator to identify and document any fractures and/or penetration (both of the skin simulant layer and of the underlying bone, including quantifying the extent to which penetration occurred – i.e. just the spear, or both the spear and the probe body). Photographs were taken to document the effect on the model (and, as per other testing, videos recorded of each shot). Damage was assessed using a fracture scale provided by Dstl which is believed to be consistent with other trials using these skull models:

1. No visible fracture of scapula
2. Linear fracture
3. Depressed intact fracture
4. Depressed detached fracture
5. Total fracture

Where the spear penetrated and stayed in, the remaining probe length was measured in the same manner as for the skin penetration testing (see Section 2.2), with an accuracy of $\pm 2\text{mm}$. The structure of a T10 probe for both the Old and New design are shown in Figure 1 and detailed in Section 2.2; for reference they both have a total length of 61mm, each with an 11mm spear.

Appendix C provides further information regarding the test models for this testing.

3.3 Results

Table 2 summarises the results of the skull fracture/penetration testing for the Old and New spear designs, with full results in Appendix C.

Testing		Number of shots	Effect on target				Penetrated length (mm)			
			% shots penetrated target	% shots remaining in target	% shots that left marks on the bone	% shots with bone penetration	Mean	Standard deviation	Minimum	Maximum
Previous Testing	Old Spear Design	20	100%	65%	70%	5%	20.2	4.1	16	29
	Current Testing	Old Spear Design	40	100%	65%	80%	0%	17.7	2.9	11
	New Spear Design	40	100%	68%	55%	0%	19.5	4.1	11	25

Table 2: A summary of the skull penetration results for the Old and New designs. For each shot, the occurrence of various effects (penetration of the skin layer, damage/penetration of the bone, and the probe remaining in the target) was observed/measured and combined statistics are compiled here. Where the probe remained in the target, the remaining exposed length of the probe was recorded, and the penetrated length inferred from the exposed length and the known total length of the probe (61mm).

None of the 80 shots resulted in penetration of the bone or fracturing of the bone; all scored a 1 on the fracture scale. Penetration of the skin occurred for all shots, with 65-68% of shots remaining in the target – this was consistent between the two designs. Differences between the designs were observable in the rate of marks being left on the bone, with 80% of Old design shots causing pin prick marks compared to 55% of New design shots. The penetrated length of the probe also differed slightly, with an average depth of 17.7mm for the Old design compared to 19.5mm for the New design, although this difference (1.8mm) was comparable with the standard deviation of the measurements (2.9-4.1mm) and the range of measurements (i.e. the minimum to the maximum) was highly similar. It is also important to note that the penetrated length is the length of the probe that remained in the target (ignoring cases where the probe bounced out of the target), and this will be strongly influenced by how the probe impacts the bone – e.g. a probe with higher kinetic energy at the bone could potentially bounce back more than a probe with lower kinetic energy, or a higher kinetic energy could result in greater deformation of the spear in a way that reduces the kinetic energy available for the probe to bounce back, resulting in a deeper final penetration depth. The penetrated length is therefore difficult to interpret and likely sensitive to the angle of impact of the probe on the bone (which will influence how the spear deforms), and there is not a clear difference between the Old and New designs.

Comparing the data for the Old design with previous testing data for skull penetration that also used the Old design showed broadly similar performance – both sets of data had all shots penetrating the target, 65% of shots remaining in the target, and 70-80% of shots leaving marks on the bone. The differences lay in the lack of any shots penetrating the bone in the skull comparison data, whereas in previous testing there were 2 out of 20 shots that penetrated the bone. Also, the penetration depth of the probe was higher in previous testing (20.2mm on average) than in the spear comparison data (17.7mm). This reduction in penetration depth was also observed in the skin penetration data, and could be the result of a lower temperature in the spear comparison testing, or from using different hardware and software revisions. Note also

that the nature of the bone models means that they are likely subject to more manufacturing variability than the skin simulants, so differences in the targets are another possible cause.

3.3.1 Spear deformation

Figure 2 shows how the spears on the probes used in the skull penetration testing were typically subjected to substantial deformation and warping due to the impact with the bone. For both spear designs there were instances of the spear (and sometimes the impact absorber) being bent approximately 90°. This could make it more difficult to remove from a target, but there is minimal evidence from this testing that there is a clear difference in how the different spear designs deform. The only potential insight identified is that the Old design typically had more deformation of the tip (the ~2-3mm nearest the sharp end of the spear), whereas the New design more often had the tip still parallel to the rest of the spear, although there are also multiple examples of the New design being bent at the tip. The cause of this slight difference is assumed to be due to the rectangular profile of the New design compared to the tapering cylinder profile of the Old design, which results in a narrower (and therefore less resistant to bending forces) tip for the Old design. It is not clear if this would translated to any practical or operational difference in how difficult the different designs are to remove from a target.



Figure 2: Photographs of the probes used for skull penetration testing, showing the amount and variation of the spear deformation due to impact with the bone. In both photographs (which show different angles of the same arrangement of probes), the top row of probes have the New spear design and the bottom row have the Old design.

3.4 Conclusions

All shots for both spear designs scored a 1 on the fracture scale provided by Dstl, with no shots penetrating or fracturing the skull. The rate of bounce-outs was highly similar (32-35%) for both spear designs, and the biggest difference was a higher rate of pin prick marks being left on the bone by the Old design (80%) than the New design (55%). Given that the New design was observed to penetrate deeper than the Old design in the skin penetration testing (see Section 2), the higher rate of pin pricks from the Old design could seem counterintuitive but is likely due to the specifics of how the spear tip impacts the bone – the Old design appears to have a more

acute tip angle (see Figure 1) which could enable it to more easily make pin prick marks even with similar or lower kinetic energy at the bone (after penetrating through the skin simulant layers) than the New design.

The performance of the Old design was observed to be similar between the spear comparison testing and previous testing, aside from the absence of any bone penetration or fracture in the spear comparison testing. This could, as with the skin penetration testing, be due to a lower ambient temperature or differences due to the hardware/software revisions, and the bone models are also likely more variable than the skin simulant targets due to the manufacturing process involved.

Note also that the data in this chapter used clamped devices, and it has been previously identified that hand-fired devices appear to exhibit a small (2.5%) decrease in average velocity and an increase in the velocity spread, compared to clamped devices (see previous testing⁷). The results in this chapter therefore represent a worst-case scenario when considering the injury-causing potential of devices.

⁷ Report MIQ-24-0014-D - Taser 10 Technical Testing Results

4 Kinetics: Accuracy & kinetic energy

4.1 Purpose

The purpose of this test was to assess the impact of the different spear designs on the accuracy of the T10 and its ability to achieve reliable probe placement at different range, and, additionally, to measure the kinetic energy of the probes at different ranges (to again provide a comparison between the spear designs).

4.2 Methodology

The same methodology as for the previous accuracy testing was used. To summarise:

- A fixed firing rig was used to securely hold the T10 device, which was fired at a flat Axon-provided target (consisting of multiple high-density foam layers with a conductive layer included, all mounted to a plywood backboard with spacers to allow the target to flex when impacted by probes, minimising the risk of bounce-outs) covered with graph paper to allow both the point of aim (POA – where the laser sight was on the target) and the point of impact (POI – where the probe hit the target) to be measured to an accuracy of 1mm in the horizontal (x) and vertical (y) directions. The POI was recorded relative to the POA, and any changes to the POA after firing were also recorded.
- Mass measurements of a subset of deployed probes were made by cutting the wire at the base of the projectile after being fired into the target, then using a weighing scale to measure the probe mass individually.
- Velocity measurements of a subset of deployed probes were recorded using a chronograph with a gate separation of 300mm, which records the average velocity of a probe as it passes between the two gates of the chronograph. The velocity measurements were taken as close to the target as possible (to allow the kinetic energy to be estimated by combining the velocity and mass measurements) but the non-zero gate separation limited how close to the target the velocity could be measured.
- All tests used the same magazine and handle to provide consistency. Note that there were some differences in versions of the hardware used for this testing compared to previous testing (see Table 3) – the specific details of the changes between these revisions were not known to the testing team or the authors of this report.

T10 Hardware / Software	Revision	
	Previous Testing	Spear Comparison Testing
Handle	D	J
Handle Firmware	1.5.3	1.6.32
Magazine	A	E
Battery	F1	F

Table 3: Summary of differences in revision numbers for hardware and software between the spear comparison testing and previous testing.⁸

Using this methodology, three full magazines of each spear design (60 total shots; 30 of each spear design) were fired at the target, with the POA and POI recorded for each shot. This was

⁸ Report MIQ-24-0014-D - Taser 10 Technical Testing Results

repeated for three different ranges: 10.1m (the ‘zero range’ where the laser marker and POI is intended to be in closest alignment); 13.4m (close to the maximum range, and slightly reduced from the 13.7m used previously for long range testing to minimise the chance of any wires breaking); and 3.0m (a close contact range where some probe trajectory instability could be possible). The total number of shots was therefore 180 across all ranges and spear designs. Details of the CED hardware and cartridge used for each shot are recorded in Appendix A.

4.3 Results

The results are broken down into multiple sections that consider the accuracy, mass, velocity, momentum and kinetic energy of the probes.

4.3.1 Probe accuracy

Figure 3 shows the measured POI data for both spear designs, with data from previous testing shown for comparison. A summary of the POI statistics is provided in Table 4.

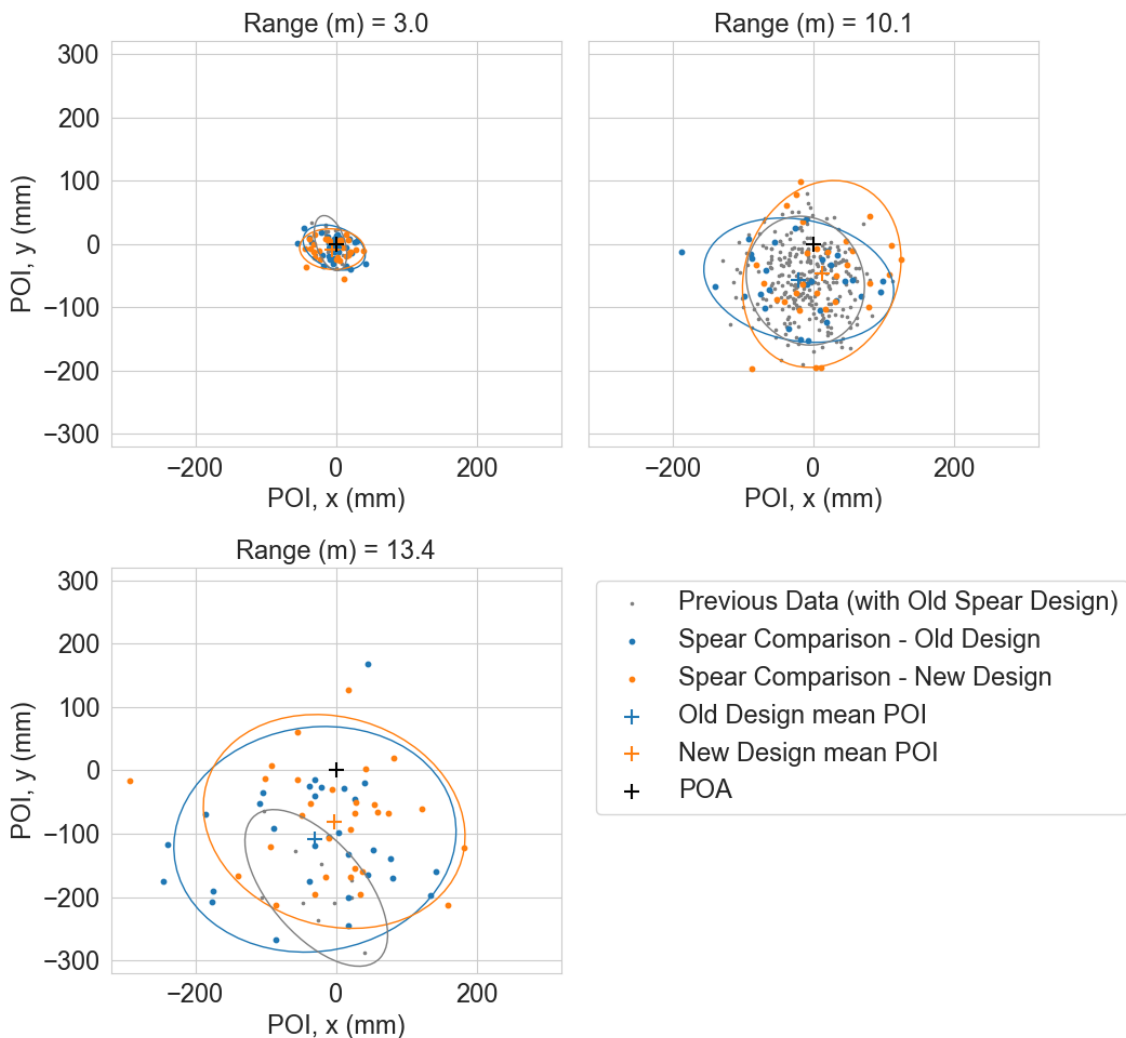


Figure 3: Plots of POI data at different ranges for Old and New spear designs, with data from previous accuracy testing shown for comparison (in grey, noting that for 13.4m there is no previous data at that precise range, so previous data from 13.7m is shown). The black cross indicates the POA, the blue and orange points are the raw POIs for the Old and New designs respectively, and ellipses are the confidence ellipses that correspond to containing 95% of the data.

Spear Design	Range (m)	Measurement Count	POI, x (mm)		POI, y (mm)		POI, r (mm)	
			Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Old Design	3.0	30	-2.3	22.1	-5.9	17.9	24.7	14.7
	10.1	30	-20.9	67.5	-57.5	49.1	93.5	42.3
	13.4	30	-29.7	100.3	-108.9	89.1	153.0	83.4
New Design	3.0	30	-5.1	23.2	-8.5	16.1	26.5	13.0
	10.1	30	11.8	56.4	-47.6	73.8	92.0	48.5
	13.4	30	-2.3	93.0	-80.7	84.5	131.2	68.8

Table 4: A summary of the dispersion of shots using Old and New spear designs from a single duty magazine at different ranges. x, y and r are the distance between the POA and the POI in the horizontal, vertical and radial directions, respectively. This is a summary of the data in Figure 3.

Figure 4, Figure 5 and Figure 6 plot the variation in the horizontal, vertical and radial POI, respectively, for the Old and New spear designs, with the all previous Duty cartridge data shown for comparison. There is a high degree of overlap between the Old and New design data for all three measured ranges, indicating that (within the level of statistical confidence afforded by the amount of data in this testing) no significant difference in accuracy has been demonstrated.

Comparing the spear comparison data with the previous data highlights some subtle differences. Compared to the previous data, the spear comparison data shows:

- Noticeably higher spread in the x-direction at short range (3.6m), but similar spread in the y direction
- Highly similar performance at 10.1m, in both x and y directions (and therefore also in r)
- Significantly greater spread in both x and y at long range (comparing 13.4m range for the spear comparison data to 13.7m for the previous data), but more centred around the POA, so more accurate on average but with higher shot-to-shot variation.

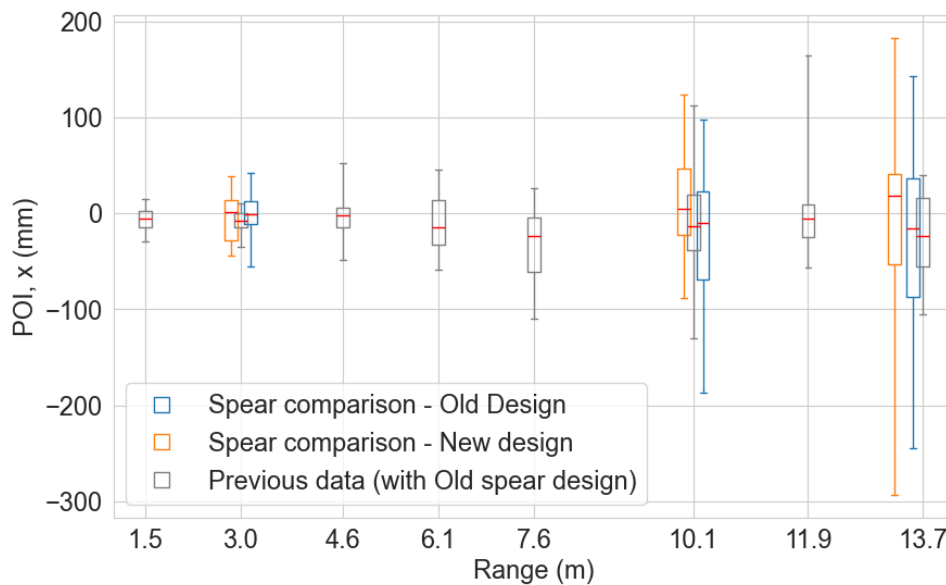


Figure 4: Box plots of POI data in the x direction (horizontal) at different ranges for different spear designs using a single magazine, with all previous Duty cartridge data for comparison (which used the Old design). The boxes for a given range are slightly offset along the range axis to avoid overlap (noting that the long range spear comparison data was taken at 13.4m, not

13.7m as in the previous data). The boxes show the interquartile range, the whiskers extend to the minimum and maximum values, and the red line is the median value.

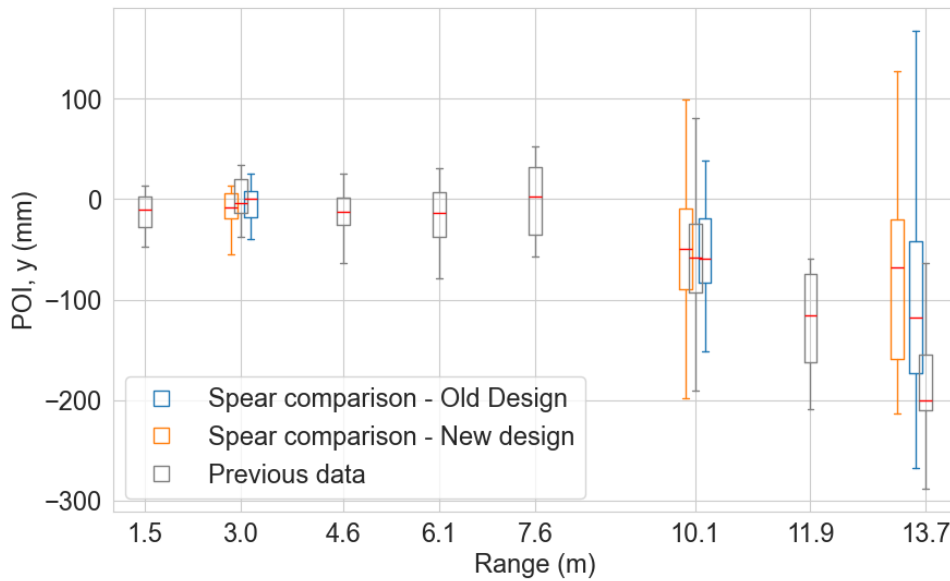


Figure 5: Box plots of POI data in the y direction (vertical) at different ranges for different spear designs using a single magazine, with all previous Duty cartridge data for comparison (which used the Old design). The boxes for a given range are slightly offset along the range axis to avoid overlap (noting that the long range spear comparison data was taken at 13.4m, not 13.7m as in the previous data). The boxes show the interquartile range, the whiskers extend to the minimum and maximum values, and the red line is the median value.

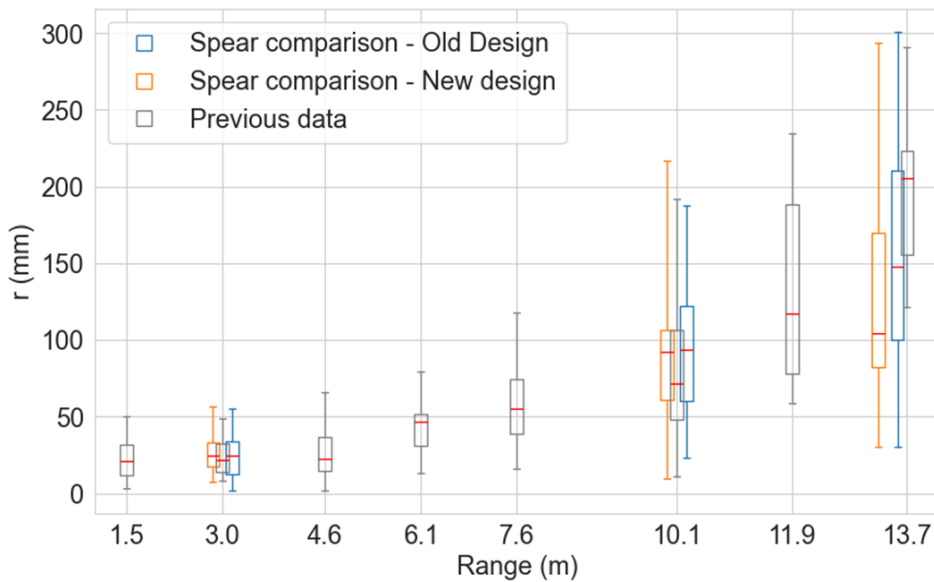


Figure 6: Box plots of POI data in the r direction (radial) at different ranges for different spear designs using a single magazine, with all previous Duty cartridge data for comparison (which used the Old design). The boxes for a given range are slightly offset along the range axis to avoid overlap (noting that the long range spear comparison data was taken at 13.4m, not 13.7m as in the previous data). The boxes show the interquartile range, the whiskers extend to the minimum and maximum values, and the red line is the median value.

4.3.2 Probe mass

The probe mass data is shown in Figure 7 with summary statistics in Table 5. The spear comparison mass data matches well with the linear reduction with distance (63mg per metre) from previous testing data. In particular:

- At 3.0m, the average probe mass for both probe designs was essentially identical (within 0.004g), although a noticeably higher standard deviation (i.e. spread of measurements) for the New design (0.031g) than the Old design or previous data (0.008g) for both. In practice, 0.031g still corresponds to a variation of less than 1% of the average probe mass, so will have a similarly small impact on the kinetic energy.
- At 10.1m, the old design and previous data were highly similar, with the new design measuring slightly heavier on average (~0.02g), but still only a difference of less than 1%, and with a similar spread.
- At 13.4m, the new design was again slightly heavier than the old design on average (0.024g on average – 0.82% of the average weight) with a similar spread. Extrapolating previous measurement data at 13.7m to 13.4m indicated that it was again in line with the mass of the old design.

Overall, the masses of the Old and New spear designs are highly similar, with the New design showing a marginally heavier mass (<1%) at 10.1m and 13.7m, with a higher spread at 3.0m.

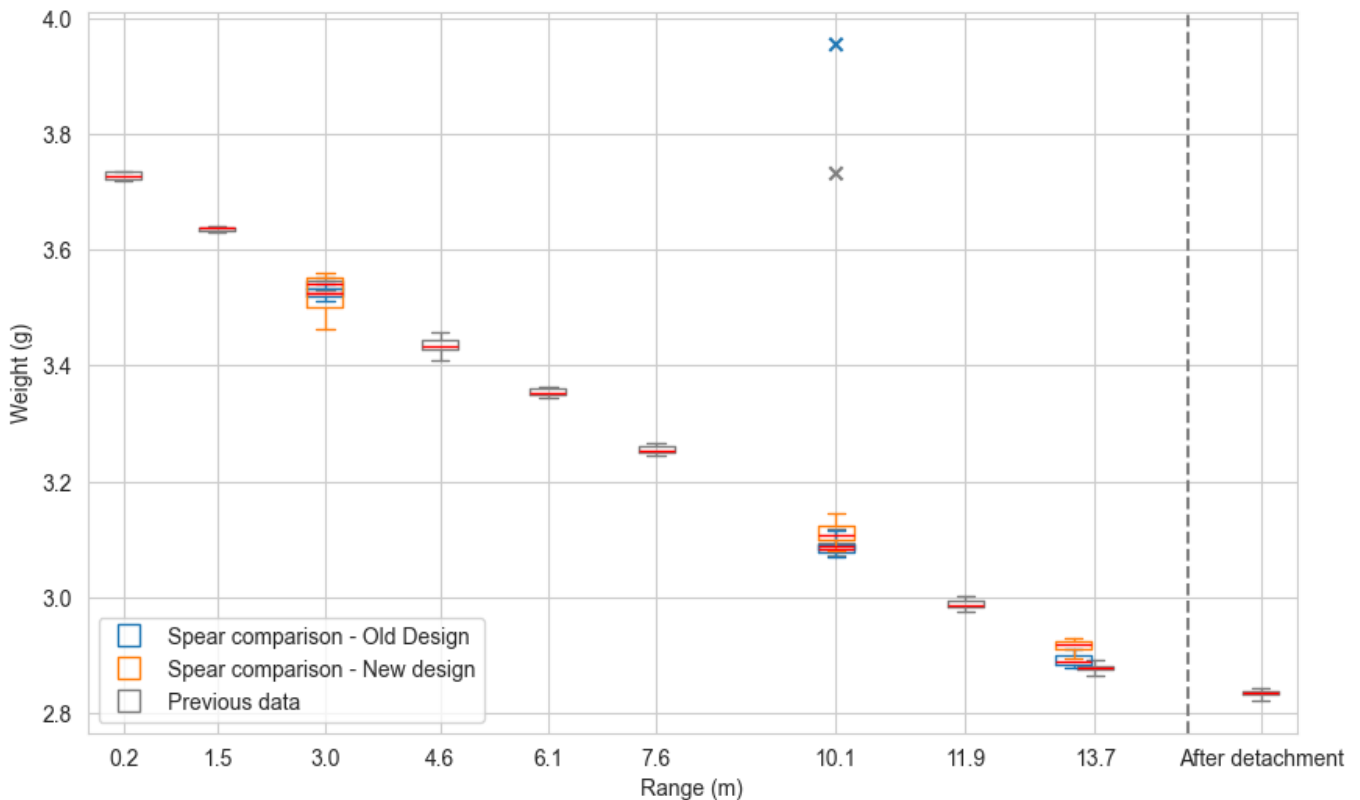


Figure 7: Plots of the probe mass measured at different ranges, with the spear comparison data for Old and New designs shown in blue and orange respectively, and previous data shown for comparison in grey. The grey x is an outlier shot where the wire detached in the bay (all the wire remained inside the probe and travelled with it), and the blue outlier is believed to be a data input mistake – the value was 3.9550g, and was likely meant to be 3.0955g. The boxes show the interquartile range, the whiskers extend to the minimum and maximum values, and the red line is the median value. The vertical dotted line indicates the point beyond which detachment regularly occurred (15m).

Data	Range (m)	Measurement Count	Probe mass (g)				
			Mean	Maximum	Minimum	Standard deviation	Standard error
Spear comparison - Old design	3.0	25	3.526	3.541	3.512	0.008	0.002
	10.1	11	3.086	3.116	3.069	0.014	0.004
	13.4	12	2.892	2.910	2.878	0.011	0.003
Spear comparison - New design	3.0	27	3.522	3.562	3.464	0.031	0.006
	10.1	14	3.111	3.145	3.082	0.018	0.005
	13.4	12	2.916	2.930	2.895	0.011	0.003
Previous testing (with Old design)	0.2	5	3.728	3.736	3.718	0.008	0.003
	1.5	10	3.637	3.643	3.630	0.004	0.001
	3.0	10	3.541	3.552	3.530	0.008	0.002
	4.6	20	3.435	3.458	3.409	0.013	0.003
	6.1	10	3.354	3.362	3.346	0.006	0.002
	7.6	10	3.255	3.268	3.246	0.008	0.003
	10.1	49	3.089	3.118	3.073	0.009	0.001
	11.9	10	2.988	3.002	2.976	0.009	0.003
	13.7	10	2.878	2.892	2.865	0.008	0.002
	Beyond detachment	10	2.834	2.844	2.822	0.006	0.002

Table 5: Statistics for the mass of probes at different ranges, excluding the outliers identified in Figure 7.

4.3.3 Probe velocity

The probe velocity data is shown in Figure 8 and Figure 9 with summary statistics in Table 6. As with previous data, the shot-to-shot variation is significantly higher for velocity than for mass. The New design has noticeably higher spread in velocities at each range than the Old design, but this is driven by a small number of outliers, and most velocity measurements are highly comparable – the average velocity of both designs are within 3% of each other at each range. It is unclear exactly what the source of two outliers at 9.625m range were, but otherwise there are no significant differences in the measured velocities of the different spear designs. Upon reviewing the high speed video of the shots, the shot with the anomalously high velocity at 3.0m was observed to have caused the chronograph to visibly wobble, which may explain the reading and resulted in it being excluded from the velocity analysis; the 2 anomalously high velocities at 10.1m did not show any similar behaviour, so were included in the analysis. It is possible that the unusually high velocity measurements are real rather than artefacts of the measurement setup, with the cause unclear.

Direct comparison with previous data is complicated by not having data at exactly the same ranges (due to time constraints requiring velocity data to be taken at the same time as accuracy data for spear comparison testing, and the gate length of the chronograph requiring the velocity measurements to be taken slightly in front of the target), but the spear comparison data for both spear designs appears to fit well with the slight linear decrease over distance observed previously.

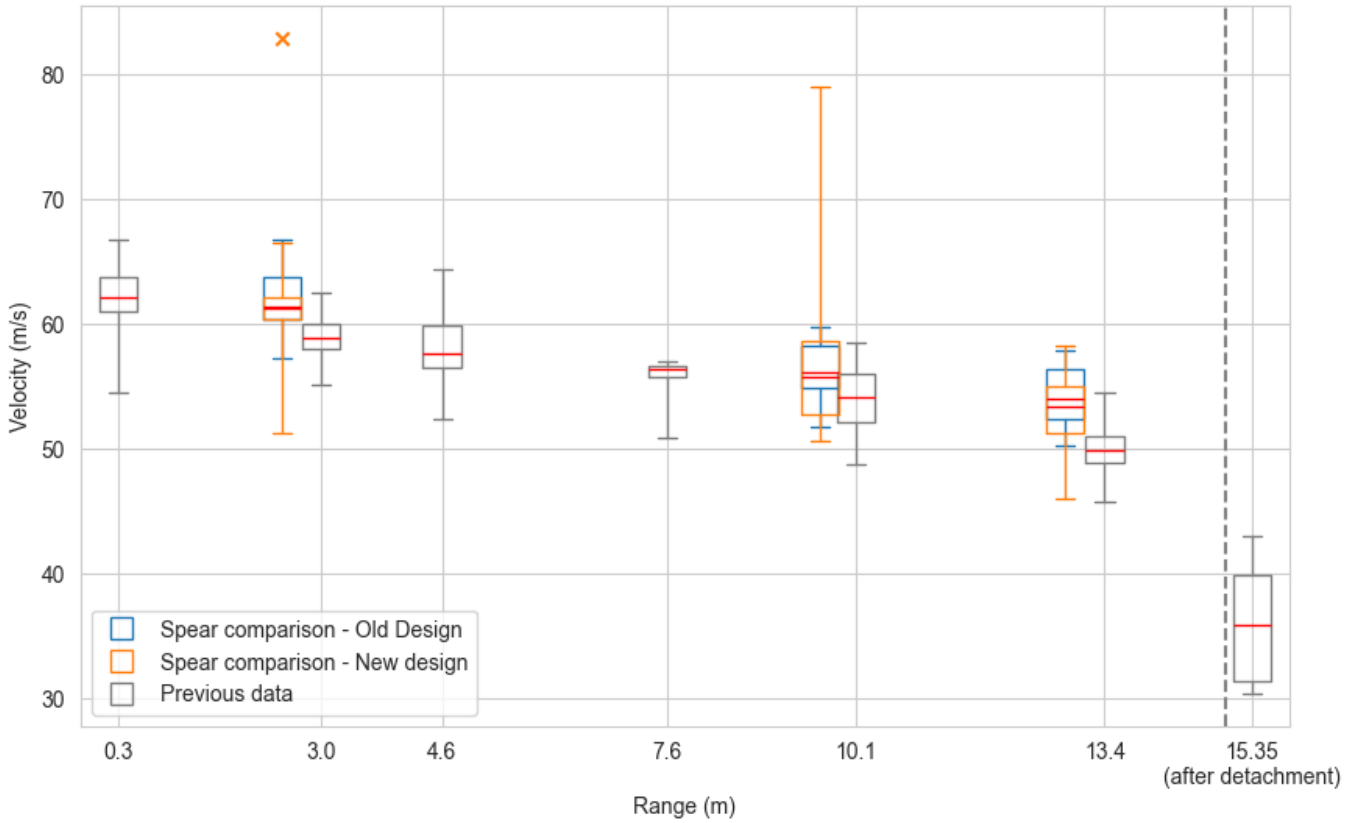


Figure 8: A box plot of the probe velocity at different ranges, with the spear comparison data for Old and New designs shown in blue and orange respectively, and previous data shown for comparison in grey. The boxes show the interquartile range, the whiskers extend to the minimum and maximum values, and the red line is the median value. The x marks an outlier excluded from analysis on the basis it made the chronograph visibly wobble (based on reviewing video footage). The vertical dotted line indicates the point beyond which detachment regularly occurred (15m).

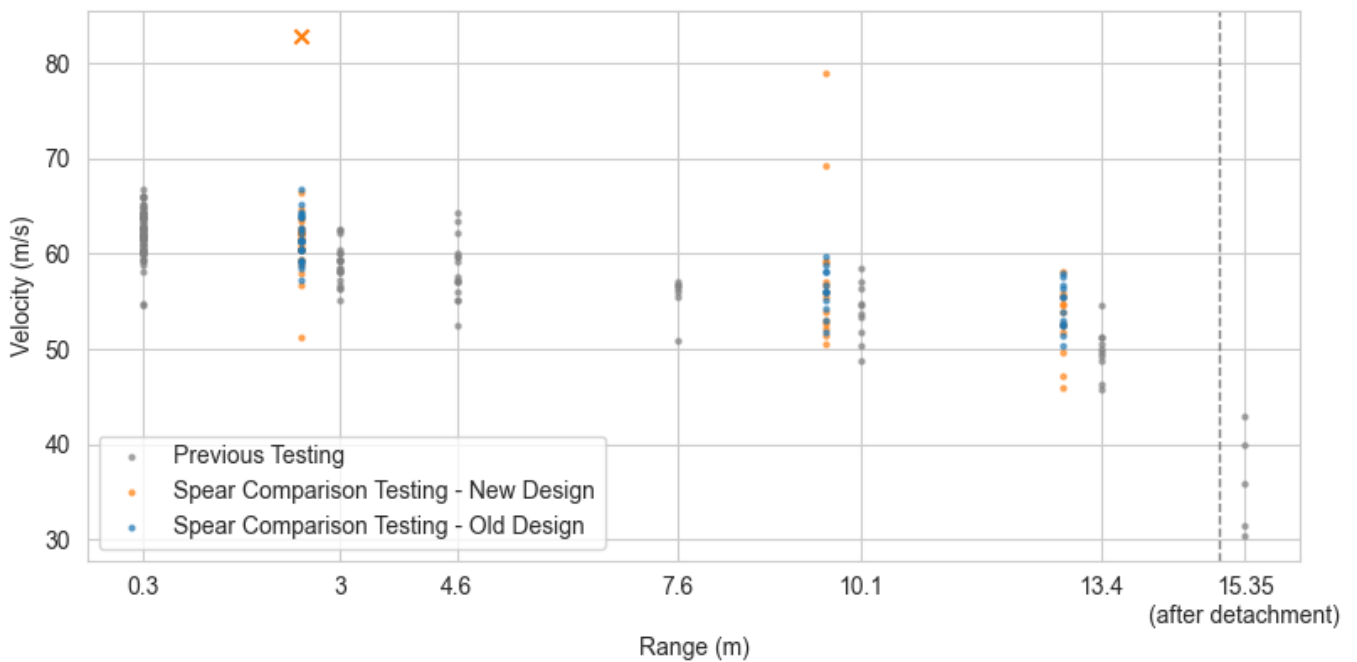


Figure 9: A scatter plot of the probe velocity at different ranges, with the spear comparison data for Old and New designs shown in blue and orange respectively, and previous data shown for comparison in grey. The x marks an outlier excluded from analysis on the basis it made the

chronograph visibly wobble (based on reviewing video footage). The vertical dotted line indicates the point beyond which detachment regularly occurred (15m). This is the same data as in Figure 8, but showing individual data points to highlight how a few outliers for the New design are responsible for the noticeably higher spread shown in the boxes of Figure 8.

Data	Range (m)	Measurement Count	Probe velocity (m/s)				
			Mean	Maximum	Minimum	Standard deviation	Standard error
Spear comparison - Old design	2.47	25	61.62	66.75	57.30	2.35	0.47
	9.625	12	56.18	59.74	51.82	2.37	0.68
	12.87	13	54.30	57.91	50.29	2.45	0.68
Spear comparison - New design	2.47	27	60.96	66.45	51.21	2.85	0.56
	9.625	14	57.54	78.94	50.60	7.73	2.07
	12.87	12	52.73	58.22	46.02	3.59	1.04
Previous testing (with Old design)	0.3	70	62.24	66.75	54.56	2.35	0.28
	3	20	58.93	62.48	55.17	2.02	0.45
	4.6	15	58.42	64.31	52.43	3.26	0.84
	7.6	7	55.60	57.00	50.90	2.13	0.81
	10.1	10	53.92	58.52	48.77	3.03	0.96
	13.4	10	49.74	54.56	45.72	2.52	0.80
	15.35m (after detachment)	5	36.15	42.98	30.48	5.38	2.41

Table 6: Statistics for the velocity of probes at different ranges.

4.3.4 Probe momentum & kinetic energy

Table 7 summarises the momentum and kinetic energy calculated at different ranges from the corresponding mass and velocity data. The variability in velocity (relative to the mean velocity) is significantly higher than for the mass; the uncertainty in velocity is therefore the main source of error in calculating the momentum and kinetic energy. The mass data was adjusted to account for the slight difference in range that the mass and range data was taken at – the mass data was adjusted using the 62.9mg/m linear fit found from previous weight measurement testing. This adjustment amounted to a 0.9-1.2% change in the masses, and correspondingly in the final calculated values of the momentum and kinetic energy (i.e. comparable to or less than the uncertainty from the velocity measurement variation).

		Spear comparison - Old design			Spear comparison - New design		
		2.47m	9.625m	12.87m	2.47m	9.625m	12.87m
Velocity (m/s)	Mean	61.62	56.18	54.30	60.96	57.54	52.73
	Standard deviation	2.35	2.37	2.45	2.85	7.73	3.59
	Standard error	0.47	0.68	0.68	0.56	2.07	1.04
Mass (g)	Mean	3.493	3.056	2.859	3.489	3.081	2.883
	Standard deviation	0.008	0.014	0.011	0.031	0.018	0.018
	Standard error	0.002	0.004	0.003	0.006	0.005	0.005
Momentum (kg m /s)	Mean	0.215	0.172	0.155	0.213	0.177	0.152
	Standard deviation	0.008	0.007	0.007	0.010	0.024	0.010
	Standard error	0.002	0.002	0.002	0.002	0.006	0.003
Kinetic energy (J)	Mean	6.63	4.82	4.21	6.48	5.10	4.01
	Standard deviation	0.51	0.41	0.38	0.61	1.37	0.55
	Standard error	0.10	0.12	0.11	0.12	0.37	0.16

*Table 7: Summary statistics for the velocity and mass of New and Old designs at different ranges, with the corresponding calculated momentum and kinetic energy. * the probe masses were adjusted using a linear extrapolation (62.9mg/m to match the ranges for which velocity measurements were taken).*

The momentum and kinetic energy data at each range is similar for both spear designs (as expected based on the highly similar mass and velocity data for both designs) – the mean values are consistently within 1 standard deviation of each other. There is therefore no evidence of any statistically significant differences in the kinetic energy or momentum of the Old and New spear designs on average. The results also align closely with the results of previous testing (as expected from the similar mass and velocity data) – for example, previous testing measured a kinetic energy of 4.49J at 10.1m with a standard deviation of 0.50J, compared to 4.82J and 5.10J at 9.625m for the Old and New designs, respectively, in the spear comparison data.

An important caveat is that the two anomalously high velocities for the New design at 9.625m were 20% and 37% higher than the mean velocity at that range (57.54m/s), while the mass for both were not anomalous. Using these velocity measurements, the kinetic energy of the two shots would be 9.71J and 7.38J, respectively (90% and 45% higher than the average kinetic energy of 5.10J for that range). These would be significantly different to any shots for the Old Design or in previous design, but it remains unclear what the cause of these anomalously high velocity measurements were – reviewing video footage did not show any evidence of unusual behaviour, although a similar outlier was observed to make the chronograph wobble, so it is conceivable that a similar but less observable interaction with the chronograph could be the cause. Looking at the POI data, the 7.38J shot impacted in the middle of the spread of shots at that range, while the 9.71J shot had the second highest impact point. Overall, it is not clear based on the available evidence whether these anomalous velocity measurements are the result of a measurement artefact or a real result.

Note that the spear comparison data used clamped devices, and it has been previously identified that hand-fired devices appear to exhibit a small (2.5%) decrease in average velocity

and an increase in the velocity spread, compared to clamped devices (see previous report⁹). The results in this chapter may therefore be a slight overestimate of the velocity, momentum and kinetic energy of probes that are hand-fired.

4.4 Conclusions

Based on the POI data collected in this testing, there was no evidence for any significant difference in behaviour for the Old and New designs of spears – the average accuracy relative to the POA, as well as the spread in the vertical and horizontal, was highly similar at all three tested ranges, within the limits of statistical significance possible by the number of shots. Repeating testing with a substantially higher number of shots could identify small differences in average behaviour between the spear designs, although it is unlikely that this would translate into an operationally detectable difference.

Similarly, the average measurements of the mass, velocity, momentum and kinetic energy of the Old and New probes were highly similar, with no significant differences identified, and good alignment with data from previous testing. The spread of the results were also generally similar, with the exception of two outlier velocity measurements at 9.625m range that were 20-37% higher than the average velocity, corresponding to a 45-90% higher kinetic energy of 7.38-9.71J. It is possible that these are artefacts of the measurement system (given a similar outlier was observed to cause the chronograph to wobble, and excluded on that basis), but there is no direct evidence to confirm that these are erroneous, so are included in the analysis and should be considered as potential extreme cases without further evidence.

Comparing the accuracy data collected in this spear comparison testing with data from Duty cartridges in previous testing indicates small changes in accuracy, particularly at long range (13.4-13.7m) where the previous data showed lower spread but reduced average accuracy relative to the POA – specifically, the previous data tended to drift further vertically from the POA. In contrast, the data at 10.1m showed no significant differences between the spear comparison testing data and the previous data, while at short range (3.0m) there was an increase in spread in the horizontal direction, but no significant change in the average accuracy relative to the POA. Noting that the previous testing used different revisions of the handle, magazine and firmware, this could be explained by incremental improvements in the device, although it is unclear without knowing the precise changes what could be the underlying cause. Overall, the Old and New spear designs appear to produce highly similar accuracy results, while some small changes to accuracy performance compared to previous data have been observed, particularly at high range, and may be due to hardware or software revisions.

⁹ Report MIQ-24-0014-D - Taser 10 Technical Testing Results

5 Other observations

Shot 1700/A at 10.1m range showed anomalous behaviour by impacting approximately 230mm left of the POA (i.e. it veered strongly left). Upon inspection, the wire was observed to have deployed in a twisted pattern (see Figure 10); it appears that the wire had not been wound correctly in the projectile. Shot 1700/A was excluded from the analysis as a result and retaken as 1700/B.

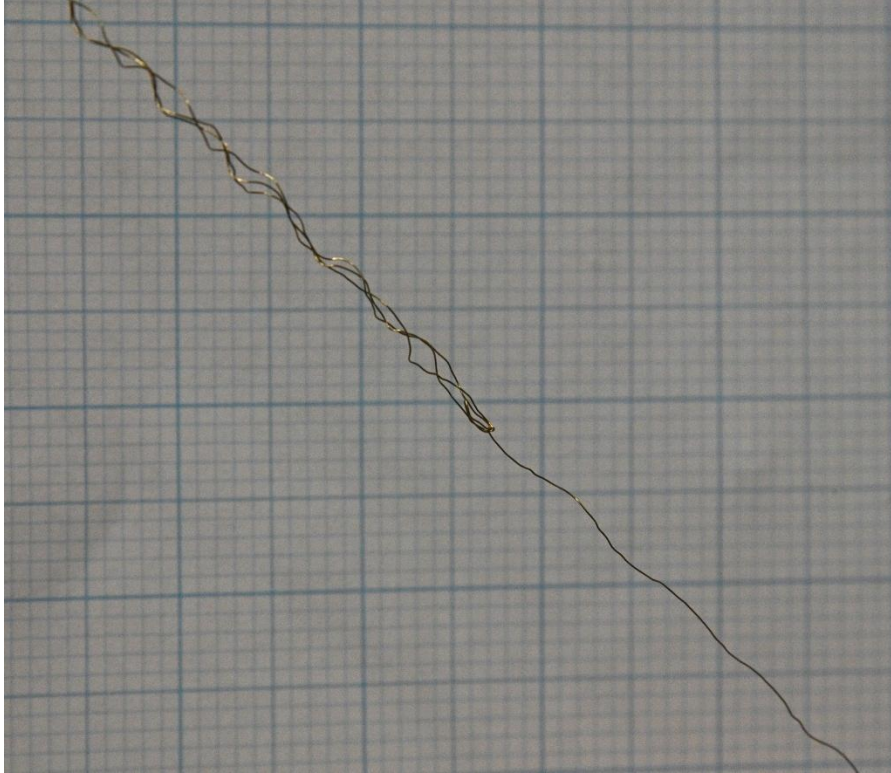


Figure 10: A photograph of the wire after shot 1700/A was observed to veer left of the target by ~230mm.

Appendices

Appendix A Raw testing data

Appendix A consists of the raw testing data (including all equipment numbers), which is provided alongside this report as a spreadsheet: *MIQ-24-0015-D - Taser 10 Technical Testing Data*. Note that where the Attempt is listed as B or C for spear comparison testing data, this was the result of a previous attempt hitting the chronograph (due to the chronograph being placed very close to the target in order to capture velocity data near the target at the same time as capturing accuracy data, given the tight time constraints on testing) – such an attempt was disregarded and retaken.

Appendix B Skin penetration

Equipment

The skin simulant target was a TP5 Biofidelic Shoot Pack from Biokinetics, provided by Dstl. Each pack measured approximately 15.5"x18" and were composed of multiple layers of rubber of varying hardness to replicate the different layers of skin. The composition of the packs was:

1. An outer layer of 1.6mm SM124 grade SRR, to replicate the dermis layer
 - a. Note that the original outer layer is a different material provided by Biokinetics, with an average thickness of 1.3mm, which was replaced for by Dstl.
2. A secondary layer to replicate the epidermis, with a nominal thickness of 6.4±1.0mm.
3. 12 subsequent layers to replicate soft tissue, each layer having a nominal thickness of 6.4±1.0mm.

The minimum assembled thickness of the skin simulant pack was 69.8mm.

Details of the CED hardware and cartridge used for each shot are recorded in Appendix A.

Methodology

A summary of the methodology including the classification system is provided in Section 2.2 and based on the methodology used in previous skin penetration testing.

Data

The full results of the skin penetration tests are provided in Table 8 with a summary of the results in Table 1 in Section 2.3. The data and summary are also available in Appendix A.

Shot ID	Device	Observations	Spear penetration	Perforation: Impact absorber penetration	Perforation: Probe body penetration	Probe remained in the target	Remaining exposed length (mm)	Penetrated length (mm)
1501	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1502	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1503	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1504	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1505	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1506	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1507	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1508	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	39	22
1509	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1510	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1511	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23

Shot ID	Device	Observations	Spear penetration	Perforation: Impact absorber penetration	Perforation: Probe body penetration	Probe remained in the target	Remaining exposed length (mm)	Penetrated length (mm)
1512	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1513	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	39	22
1514	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	42	19
1515	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1516	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	40	21
1517	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1518	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	42	19
1519	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1520	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1521	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	41	20
1522	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	40	21
1523	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	39	22
1524	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1525	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	39	22
1526	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1527	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1528	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1529	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	38	23
1530	Old Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	40	21
1531	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	35	26
1532	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	32	29
1533	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	35	26
1534	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	35	26
1535	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	32	29
1536	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	32	29
1537	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	35	26
1538	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	31	30
1539	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1540	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	31	30
1541	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	34	27
1542	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1543	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	34	27
1544	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1545	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	32	29
1546	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	34	27
1547	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	34	27

Shot ID	Device	Observations	Spear penetration	Perforation: Impact absorber penetration	Perforation: Probe body penetration	Probe remained in the target	Remaining exposed length (mm)	Penetrated length (mm)
1548	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1549	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	33	28
1550	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1551	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1552	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1553	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	30	31
1554	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	32	29
1555	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	35	26
1556	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	35	26
1557	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●	●	●	31	30
1558	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1559	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	37	24
1560	New Spear Design	Probe and buffer assembly penetrated and stayed in.	●	●		●	36	25
1821	New Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	35	26
1822	Old Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	37	24
1823	New Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	37	24
1824	Old Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	42	19
1825	New Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	35	26
1826	Old Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	39	22
1827	New Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	34	27
1828	Old Spear Design	One of 8 shots taken into a single target, alternating between Old and New designs, to minimise shot-to-shot variation.	●	●		●	37	24

Table 8: Skin penetration results for T10 probes with Old and New spear designs. For each shot, the occurrence of various effects (spear penetration, impact absorber penetration, probe body penetration, and the probe remaining in the target) are denoted by the green icons. The remaining exposed length of the probe was recorded, and the penetrated length inferred from the exposed length and the known total length of the probe (61mm).

Appendix C Skull fracture/penetration

Equipment

The Dstl models were comprised of bovine scapulae, to represent the human skull, with the skin and underlying tissue represented with graded chamois and tissue simulant, respectively.

Bovine scapula was used because a region of the bovine scapula has been previously shown by Dstl to behave similarly to certain areas of the human calvarium under low velocity impact.

Due to time constraints, the models were transported in unrefrigerated storage directly from Dstl to the testing facility in Norfolk (taking approximately 5 hours), then kept in refrigerated storage at 4°C until they were used. All data was taken within the 48 hour Dstl-defined 'shelf-life' of the models.

Details of the CED hardware and cartridge used for each shot are recorded in Appendix A.

Methodology

The methodology is summarised in Section 3.2 and was based on the methodology used for the previous skull penetration testing. Bay 10 was used for every shot for consistency.

Data

The full results of the skull penetration tests are provided in Table 9 with a summary of the results in Table 2 in Section 3.3. The data and summary are also available in Appendix A.

CED type	Shot ID	Observations	Fracture scale	Remaining exposed length (mm)	Penetrated length (mm)	Skin penetration	Remained in the target	Mark on bone	Bone penetration
Old Spear Design	1561	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	46	-	●	●	●	
Old Spear Design	1562	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1563	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	46	-	●	●	●	
Old Spear Design	1564	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	43	-	●	●	●	
Old Spear Design	1565	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	40	-	●	●	●	
Old Spear Design	1566	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	46	-	●	●	●	
Old Spear Design	1567	Bounced. Yaw mark on skin. Distorted spear. No mark on bone.	1	-	-	●			
Old Spear Design	1568	Bounced. Distorted spear. No mark on bone.	1	-	-	●			
Old Spear Design	1569	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	45	-	●	●	●	
Old Spear Design	1570	Bounced. Distorted spear. Minor pin-prick on bone with slight spalling.	1	-	-	●		●	
Old Spear Design	1571	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1572	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone with minor spalling.	1	38	-	●	●	●	

CED type	Shot ID	Observations	Fracture scale	Remaining exposed length (mm)	Penetrated length (mm)	Skin penetration	Remained in the target	Mark on bone	Bone penetration
Old Spear Design	1573	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1574	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	44	-	●	●	●	
Old Spear Design	1575	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1576	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1577	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1578	Bounced. Distorted spear. No mark on bone.	1	-	-	●			
Old Spear Design	1579	Bounced. Distorted spear. Minor pin-prick on bone.	1	-	-	●		●	
Old Spear Design	1580	Fully penetrated skin and stayed in. Distorted spear. Minor pin-prick on bone.	1	45	-	●		●	
Old Spear Design	1581	Fully penetrated skin and stayed in. Distorted spear. No mark on bone.	1	45	-	●	●		
Old Spear Design	1582	Fully penetrated skin and stayed in. Distorted spear. No mark on bone.	1	45	-	●	●		
Old Spear Design	1583	Bounced. Yaw mark on skin. Distorted spear. Tiny mark on bone.	1	-	-	●		●	
Old Spear Design	1584	Bounced. Yaw mark on skin. Minor pin-prick on bone with slight spalling.	1	-	-	●		●	
Old Spear Design	1585	Fully penetrated skin and stayed in. Distorted spear. Pin prick on bone.	1	45	-	●	●	●	
Old Spear Design	1586	Fully penetrated skin and stayed in. Distorted spear. No mark on bone.	1	45	-	●	●		
Old Spear Design	1587	Fully penetrated skin and stayed in. Severely distorted spear. No mark on bone.	1	40	-	●	●		
Old Spear Design	1588	Fully penetrated skin and stayed in. Spear from side of probe detached. Pin prick on bone	1	45	-	●	●	●	
Old Spear Design	1589	Fully penetrated skin and stayed in. No visible mark on bone. Probe only slightly distorted	1	45	-	●	●		
Old Spear Design	1590	Fully penetrated skin and stayed in. Severely distorted spear. Pin prick mark on bone.	1	42	-	●	●	●	
Old Spear Design	1591	Fully penetrated skin and stayed in. Tiny pin prick on bone.	1	42	-	●	●	●	
Old Spear Design	1592	Fully penetrated skin and stayed in. Pin prick on bone. Distorted spear.	1	45	-	●	●	●	
Old Spear Design	1593	Fully penetrated skin and stayed in. Severely distorted spear. Pin prick on bone	1	43	-	●	●	●	
Old Spear Design	1594	Bounced. Distorted probe. Pin prick mark on bone	1	-	-	●		●	
Old Spear Design	1595	Fully penetrated skin and stayed in. Distorted probe. Pin prick mark on bone.	1	43	-	●	●	●	
Old Spear Design	1596	Fully penetrated skin and stayed in. Distorted probe. Pin prick mark on bone.	1	39	-	●	●	●	
Old Spear Design	1597	Fully penetrated skin and stayed in. Distorted probe. Pin prick mark on bone.	1	40	-	●	●	●	
Old Spear Design	1598	Fully penetrated skin and stayed in. Probe not distorted. No mark on bone.	1	50	-	●	●	●	
Old Spear Design	1599	Fully penetrated skin and stayed in. Distorted spear. Pin prick mark on bone.	1	38	-	●	●	●	
Old Spear Design	1600	Fully penetrated skin and stayed in. Distorted spear. Pin prick mark on bone.	1	40	-	●	●	●	

CED type	Shot ID	Observations	Fracture scale	Remaining exposed length (mm)	Penetrated length (mm)	Skin penetration	Remained in the target	Mark on bone	Bone penetration
New Spear Design	1601	Bounced. Probe bent 90 degrees. No visible mark on bone.	1	-	-	●			
New Spear Design	1602	Bounced. Probe bent back. Linear scratch on bone.	1	-	-	●		●	
New Spear Design	1603	Fully penetrated skin and stayed in. Probe slightly distorted. Scratch on bone.	1	41	-	●	●	●	
New Spear Design	1604	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	40	-	●	●		
New Spear Design	1605	Bounced. Probe bent 90 degrees. Pin prick mark on bone.	1	-	-	●		●	
New Spear Design	1606	Bounced. Probe bent 90 degrees. Pin prick mark on bone.	1	-	-	●		●	
New Spear Design	1607	Bounced. Probe bent back. Pin prick mark on bone.	1	-	-	●		●	
New Spear Design	1608	Fully penetrated skin and stayed in. Probe bent. No mark on bone.	1	46	-	●	●		
New Spear Design	1609	Fully penetrated skin and stayed in. Pin prick mark on bone.	1	48	-	●	●	●	
New Spear Design	1610	Fully penetrated skin and stayed in. Probe bent back. Pin prick mark on bone.	1	42	-	●	●	●	
New Spear Design	1611	Fully penetrated skin but bounced out. Probe bent back. Pin prick mark on bone.	1	-	-	●		●	
New Spear Design	1612	Bounced. Probe bent back. Pin prick mark on bone.	1	-	-	●		●	
New Spear Design	1613	Fully penetrated skin and stayed in. Probe bent back. Pin prick mark on bone.	1	36	-	●	●	●	
New Spear Design	1614	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	41	-	●	●		
New Spear Design	1615	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	37	-	●	●		
New Spear Design	1616	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	36	-	●	●		
New Spear Design	1617	Fully penetrated skin and stayed in. Probe bent back. Slight scuff on bone.	1	38	-	●	●	●	
New Spear Design	1618	Fully penetrated skin and stayed in. Probe bent back. Slight scuff on bone.	1	41	-	●	●	●	
New Spear Design	1619	Fully penetrated skin and stayed in. Probe distorted. Pin prick mark on bone.	1	42	-	●	●	●	
New Spear Design	1620	Fully penetrated skin and stayed in. Probe bent. No visible mark on bone.	1	39	-	●	●		
New Spear Design	1621	Fully penetrated skin but bounced back. Probe bent. No mark on bone.	1	-	-	●			
New Spear Design	1622	Fully penetrated skin and stayed in. Probe bent. No mark on bone.	1	42	-	●	●		
New Spear Design	1623	Fully penetrated skin and stayed in. Probe bent back. Slight scratch on bone.	1	39	-	●	●	●	
New Spear Design	1624	Fully penetrated skin and stayed in. Probe bent back. Pin prick mark on bone.	1	43	-	●	●	●	
New Spear Design	1625	Fully penetrated skin and stayed in. Probe bent back. Pin prick mark on bone.	1	37	-	●	●	●	
New Spear Design	1626	Fully penetrated skin and stayed in. Probe bent back. Pin prick mark on bone, with slight spalling.	1	38	-	●	●	●	
New Spear Design	1627	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	37	-	●	●		
New Spear Design	1628	Fully penetrated skin but fell out. Probe bent. No mark on bone.	1	-	-	●			

CED type	Shot ID	Observations	Fracture scale	Remaining exposed length (mm)	Penetrated length (mm)	Skin penetration	Remained in the target	Mark on bone	Bone penetration
New Spear Design	1629	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	42	-	●	●		
New Spear Design	1630	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	40	-	●	●		
New Spear Design	1631	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	40	-	●	●		
New Spear Design	1632	Fully penetrated skin but bounced out. Probe bent. Deep pin prick on bone.	1	-	-	●	●	●	
New Spear Design	1633	Fully penetrated skin and stayed in. Probe slightly bent. Slight mark on bone.	1	50	-	●	●	●	
New Spear Design	1634	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	48	-	●	●		
New Spear Design	1635	Fully penetrated skin but fell out. Probe slightly bent. No mark on bone.	1	-	-	●			
New Spear Design	1636	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	50	-	●	●		
New Spear Design	1637	Fully penetrated skin but bounced out. Probe fully bent back. Pin prick on bone.	1	-	-	●		●	
New Spear Design	1638	Fully penetrated skin but bounced out. Probe slightly bent. Minor scratch on bone.	1	-	-	●		●	
New Spear Design	1639B	Fully penetrated skin and stayed in. Probe bent. Pin prick on bone.	1	43	-	●	●	●	
New Spear Design	1640	Fully penetrated skin and stayed in. Probe slightly bent. No mark on bone.	1	44	-	●	●		

Table 9: Skull penetration results for T10 probes. For each shot, the occurrence of various effects (penetration of the skin layer, damage/penetration of the bone, and the probe remaining in the target) are denoted by the green icons. Where the probe remained in the target, the remaining exposed length of the probe was recorded, and the penetrated length inferred from the exposed length and the known total length of the probe (61mm).

Appendix D Kinetics: Accuracy

Equipment

The same equipment was used as for previous accuracy testing.

Details of the CED hardware and cartridge used for each shot are recorded in Appendix A.

Methodology

The methodology is detailed in Section 4.2 and was based on the methodology used for the previous accuracy testing.

Results

Intra-magazine comparison

The POI data from the accuracy testing (see Section 4) can be used to provide a high-level review of the relative accuracy of the 10 different bays in the magazine (a single magazine was used for all the accuracy testing data to allow this comparison). Figure 11 shows the POI data separated by bay number for the spear comparison testing data (all ranges), along with previous data at 10.1m for comparison (as the furthest range with directly comparable data, noting that there is no previous data taken at 13.4m to compare with the spear comparison data at that range). Confidence ellipses are shown for a) the spear comparison data at 10.1m range (combining the data for both the Old and New designs) and b) the previous data at 10.1m range – spear comparison data at 3.0m and 13.4m are excluded from calculating the confidence intervals, but are shown (with different marker shapes) for additional context.

Overall, most bays display similar behaviour reducing POI proximity to the POA with increasing range, and, at 10.1m range, are broadly comparable with the previous data (that used a different magazine with a different reference number – see Section 4.2). Interestingly, for the spear comparison data, the central bays (bays 1, 4, 7 and 10) show a shot distribution broadly symmetrical around the POA in the horizontal axis, while the left-hand bays (from the operator's perspective; bays 3, 6 and 9) tend to shoot right of the POA and the right-hand bays (bays 2, 5 and 8) tend to shoot left of the POA. This could be explained by the magazine being designed to direct the outer bays slightly inwards towards the centre towards the line of the laser pointer. This asymmetry is more apparent in the 13.4m data, but is relatively clear in the 10.1m data, and interestingly is not apparent in the 10.1m data for the previous data – it is possible that the revisions in the magazine have included some slight changes to the bays, or that this is an artifact of the limited amount of data (4 to 8 shots per bay at each range) which prevents drawing more detailed insights on the performance of different bays, but this appears to be a real phenomena in the spear comparison data. As noted in Section 4.3, the overall accuracy of the device in the spear comparison testing was highly similar to the device used in the previous testing, despite the apparent slight differences in bays observed in the spear comparison testing.

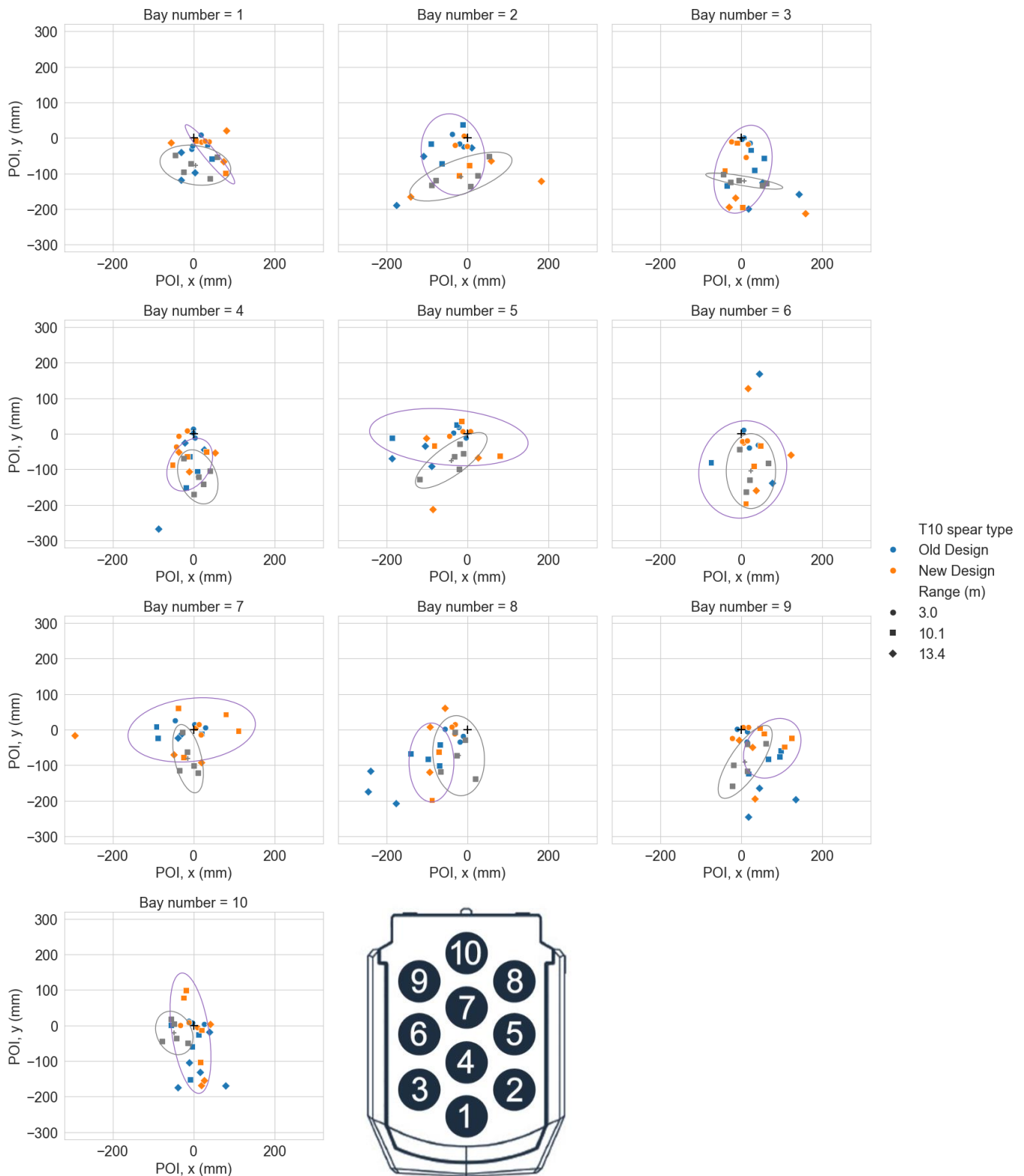


Figure 11: Plots of POI data by bay for the spear comparison accuracy testing at various ranges (in blue and orange for the Old and New designs, respectively), with previous data for duty cartridges in magazine S1 at a range of 10.1m (grey). The black cross indicates the POA, the points are the raw POIs with different marker shapes for different ranges, and the ellipses (purple for the spear comparison data at 10.1m range; grey for the previous data at 10.1m range) are confidence ellipses that correspond to containing 95% of the data, and are included to assist comparison. A diagram of the bays (from the rear of the device – i.e. the position of an operator) is provided for reference.

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