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CAST - Project DISPERSE

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1. Executive Summary

The Home Office's Centre for Applied Science and Technology (CAST) were requested by Chief Constable David Shaw, Chair of the National Police Water Cannon Project Board, to provide technical support to assess the WasserWerfer 9000 (WaWe9) water cannons that the Metropolitan Police Service (MPS) purchased from the German Police in July 2014.

As part of this, CAST were tasked with providing technical information to the Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons (SACMILL) and additionally to provide information to the Water Cannon Project Board, College of Policing and MPS on how well the WaWe9 water cannon meet the police requirement. This document summarises this information which was gathered via a series of trials conducted at the Metropolitan Police Specialist Training Centre (MPSTC) at Gravesend, Kent, between 1 September and 31 October 2014, with further tests being conducted on 1 and 2 December 2014.

Once imported the WaWe9 cannon were modified to bring the vehicles in line with UK vehicle requirements and UK police specification. Due to their bespoke nature each vehicle was individually subjected to the trials described in this document.

The trials were conducted in two phases for each vehicle:

1. Inspections to ensure that all required modifications had been completed;
2. Assessment tests to determine how well the cannon meet the requirements of the police and the recommendations in the interim SACMILL statement¹.

None of the inspections showed that there were any issues that needed resolution before the assessment of the vehicles could start.

Key points confirmed in the inspections were:

- The mechanical limitation of pump pressure to 16 bar and removal of associated controls that could select higher pressures;
- Limitation of the minimum range of the water jets to that of the PSNI Somati water cannon;
- The removal of the rear water jet monitor;
- The removal of the ability to mix in additives;
- Installation of video cameras and a PA system;
- Installation of a video based logging system.

Assessment tests had already been conducted by CAST in June 2014 on one of the PSNI Somati vehicles already in use in Northern Ireland. This provided

¹ SACMILL - 2013_11_18 Final Interim Statement WaWe 9_R

a reference set of data or benchmark for the pressure and force measurements relating to water jet outputs, minimum and maximum operational distances and control systems. Many of the assessment tests compared the data from the PSNI benchmark tests with data obtained from the testing of the WaWe9 water cannons. Other tests simply compared the outcome of the test with the technical requirement or SACMILL recommendation. In most cases a red, amber or green (RAG) status was given to the test outcome; red signified a failure to meet a particular test requirement, amber signified that a requirement was only partially met and green signified that the requirement of the test was fully met. A further category of green hatch was also introduced to signify that the requirement was met but there were some caveats.

Four failures (RAG status “red”) were encountered :

- <redacted> <redacted> <redacted> <redacted>
- <redacted>
- <redacted>
- Capability to work in indirect mode (disperse) – The WaWe9 water cannons purchased do not have the facility to diffuse the water jet to create a ‘heavy rain’ effect.

In addition to the red status there were a number of amber status where modifications to the water cannon or mitigation by the MPS will need to be considered. None of the amber or green hatch notifications would preclude the use of the cannon if the identified mitigations are carried out.

One of the more important aspects of the assessment was the measurement of the pressures and loads generated by the water cannon. The measurements have been challenging to make, primarily because of the changing structure within the water jets and because of the difficulty of placing two jets on the target. CAST have also had to take a view on how best to consider the transient peaks that the measurement system has detected, some of which are outside of its calibration or instrumented ranges.

However, the overall picture, when comparing on a single monitor basis, is that we found no evidence that the WaWe9 pressures and loads are greater than the PSNI Somati baseline. Further support for this position with regard to pressure can be inferred from the results of Test C where measured values for maximum operational distance are between <redacted> for WaWe9 than they are for PSNI Somati.

A list of the more important overall observations and recommendations (see sections 10 and 11), is listed below. The MPS will need to consider how to mitigate these issues by either risk assessment, vehicle improvements, training, guidelines for use, operational tactics or combinations thereof.

- Putting in place a robust maintenance and inspection schedule, including regular checks, particularly prior to any use, either training or operational;

- Resolving the remaining vehicle issues that were identified during the inspections and trials. These will need to be re-inspected by CAST;
- Ensuring that MPS staff become fully familiar with the vehicles, not just in terms of water jet operation;
- Developing an approach for the replacement of parts and re-testing – due to the age of the vehicles it is recommended that an agreed approach to re-testing of vehicles following the fitment of replacement parts in the future is developed. This will need to encompass the replacement of like-for-like critical parts and any design changes that are enforced by obsolescence;
- Using the vehicles regularly to avoid some of the problems encountered during the trials (this can be in training).

In addition to the above there were some actions which should be considered:

- CAST recommends limited re-testing of the PSNI Somati baseline vehicles to verify the stability of the pressure measurement system, although CAST already have good evidence over the three month period of testing the WaWe9s. It is also recommended that steps are taken (by brief testing or other means) to confirm that the LHS monitor of the PSNI Somati baseline vehicle is appropriately representative of those that have been used in service.
- There were some vehicle problems identified during the trials for which CAST recommends some limited re-testing: the fitting of replacement cameras to all the vehicles and the fitting of a new pressure sensor to vehicle <redacted> .
- There is no indirect spray mode on the WaWe9 vehicles. The Germans emulate an indirect mode using a developed tactic which the MPS could also consider.

2. Background

The Home Office's Centre for Applied Science and Technology (CAST) were requested by CC David Shaw, Chair of the National Police Water Cannon Project Board, to provide technical support to assess the WasserWerfer 9000 (WaWe9) water cannons that the Metropolitan Police Service (MPS) purchased from the German Police in July 2014.

As part of this, CAST were tasked with providing technical information to the Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons (SACMILL) and additionally to provide information to the Water Cannon Project Board, College of Policing and MPS on how well the WaWe9 water cannon meet the police requirement. This document summarises this information which was gathered via a series of trials conducted at the Metropolitan Police Specialist Training Centre (MPSTC) at Gravesend, Kent, between 1 September and 31 October 2014, with further tests being conducted on 1 and 2 December 2014.

Due to their bespoke nature, each of the three WaWe9 vehicles purchased were inspected and tested individually. The water cannons were operated by staff from the MPS who have been trained and accredited in accordance with College of Policing (CoP) guidelines as operators on the Police Service of Northern Ireland (PSNI) Somati RCV9000 (Somati) water cannon.

This document summarises the results of CAST's inspections and tests from the trials.

3. Trials Approach

A Technical Inspection and Assessment Protocol (test protocol v 1.0)² was developed for the CAST trials with technical colleagues from Defence Science and Technology Laboratory (Dstl), who also act as technical advisors to SACMILL.

During the trials, it became necessary to make some minor changes to the test protocol in light of practical issues that arose. These are reflected in v2.0 of the test protocol³ and the main changes are summarised in the Appendix in Section 13. Hereafter, the version that the test protocol refers to is v2.0.

The trials were conducted in two phases for each vehicle:

1. Inspections to ensure that all required modifications had been completed and the vehicles were 'ready for service' (see Section 3.2);
2. Assessment tests against reference documents (see Section 3.3).

Testing had already been conducted by CAST in June 2014 on one of the PSNI Somati vehicles to build a reference set of data for the pressure and

² Trial plan - WaWe9 - Gravesend v1.0 2014-08-28

³ Trial plan - WaWe9 - Gravesend v2.0

force measurements relating to water jet outputs, minimum and maximum operational distances and control systems.

3.1 References for the Development of Inspections and Tests

CAST developed the inspections and tests within the test protocol in order to provide information for key stakeholders: SACMILL, Chair of the National Police Water Cannon Project Board and the MPS.

The following reference documents were considered in the development of the inspections and tests:

- a. Interim Water Cannon Technical Requirements⁴ (developed from the Police Operational Requirement);
- b. Recommendations from SACMILL's Interim Statement on water cannon – November 2013⁵ ;
- c. CAST's response to the recommendations from SACMILL's Interim Statement⁶ ;
- d. MPS Standard Operating Procedure (SoP) for water cannon (Draft)⁷
- e. College of Policing training curriculum for Water Cannon⁸ .

From the responses to their recommendations, SACMILL provided informative comments to both CAST and to the Police and these were also considered in devising the inspections and tests, alongside additional points raised at CAST progress meetings with MPS and their vehicle suppliers during July and August 2014.

Note: CAST referred to the versions of the MPS and CoP documents that were available at the time of production of the test protocol, August 2014, ahead of the trials commencing in September 2014.

3.2 Inspections

As the WaWe9 vehicles were bought from Germany, a number of modifications were required to bring the vehicles in line with UK vehicle requirements and UK police specification. These needed to be completed before any trial could commence.

The inspections were included to provide an independent check against the modifications conducted by the MPS's vehicle contractors. These inspections

⁴ DISPERSE - Technical Requirements - Water Cannon Interim Option - Purchase 2013 08 16 v1.0

⁵ SACMILL - 2013_11_18 Final Interim Statement WaWe 9_R

⁶ WaWe9 - Comments against SACMILL Recommendations v3.0 2014-06-06

⁷ MPS Water Cannon SOP Version 0.4 (DRAFT)

⁸ College of Policing – National Police Public Order Training Curriculum – Module E4 – Water Cannon in Public Order – v2.03

were conducted by two members of staff from CAST once the vehicles were delivered to the MPS and before any of the tests were conducted.

The inspections did not include any items relating to road traffic regulations, London Emission Zone (LEZ) regulations or the mechanical roadworthiness of the vehicle.

3.3 Tests

The assessments (tests; analyses; demonstrations) were developed to enable data to be collated which will provide SACMILL with relevant information to assist in their production of an informed statement.

Where possible the assessments were developed to provide objective and repeatable results. However, some assessments entailed a level of subjectivity; maximum operational distance, clarity of video cameras, <redacted>.

3.4 MPS Tactics

Confirmation was received from the MPS regarding some of their planned tactics and these confirmations determined that testing against some of the requirements was no longer necessary (see Table 10 Section 8.2).

Confirmations received were:

- a loggist will be on the crew during all operational deployments
- the water cannons will NOT be used to tackle fires
- the water cannons will NOT be filled from an open water source
- the MPS will NOT be emulating indirect spray (diffuse) mode by any other tactical means.

4. Terminology

Definitions used throughout this report are:

Water Jet Monitor – the device which is used to spray water from the vehicle and control the direction of the water

Water Jet – the jet of water emitted from the water jet monitor

LHS / RHS – Left Hand Side or Right Hand Side of the vehicle or water jet when considered from the driver's seat, see Figure 1 below.

A glossary of terms and abbreviations used in this report is included in the Appendix in Section 18.

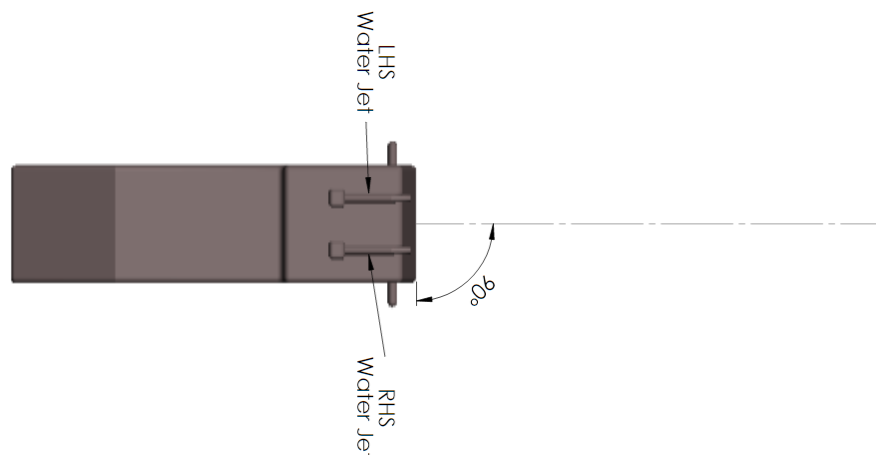


Figure 1 - Diagram Illustrating the Orientation of the LHS and RHS Water Jets

Specific terminology related to the pressure measurements can be found in Section 6.4.

5. Details of Vehicles Assessed

The WaWe9 vehicles assessed are identified in the table below:

Vehicle Tested	MPS Fleet Number	MPS Aerial ID Number	Chassis Number
Vehicle 1	<redacted>	<redacted>	<redacted>
Vehicle 2	<redacted>	<redacted>	<redacted>
Vehicle 3	<redacted>	<redacted>	<redacted>

The PSNI Somati RCV water cannon vehicle tested in June 2014 was:

Vehicle Tested	Registration
<redacted>	<redacted>

Note: It is presently assumed that this PSNI Somati vehicle is representative of the others (based upon records from when they were first built and tested).

6. Trial Progress

6.1 Vehicle Problems Found During the Trials

There were a variety of vehicle problems found during the course of the trials.

Details of vehicle failures upon delivery and significant problems that were identified during testing but resolved, can be found in the Appendix in Section 0.

Details on the specific problems identified in the inspections can be found in Section 7.1.

Some mechanical modifications were not fully completed at the time of the trials, so some of the CAST team returned early December to conclude testing on finalised modifications.

Significant problems identified but not yet rectified as at 2 December 2014 comprise:

- Vehicle 2 – broken pressure sensor on the pump engine. This failed after the specific pressure tests on Vehicle 2 had been completed. Sample re-testing by CAST should be undertaken to show that this has not adversely affected any of the pressure levels.
- All vehicles - MPS have taken the decision to replace all of the water jet monitor cameras due to further problems. The new models will need to be subjected to a partial re-test by CAST, as the camera tests completed involved the original cameras.

6.2 <redacted>Pressure Testing Environment

Due to the size and scale of the vehicles, WaWe9 testing was conducted outside at MPSTC. All the tests, except the turning circle, were conducted within the confines of the public order training simulated street environment. (The turning circle had to be conducted in the main car park).

The pressure testing conducted was subject to several variables which may have an effect on some, or all, of the results. These included:

- Variability due to structure within the water jets
 - The water jets are not stable or exactly reproducible in nature due to complex interactions and fluid dynamics effects that are continually taking place.
- Variability between individual monitors on the vehicles
 - The fluid dynamics of each water jet monitor are potentially different due to variations in mechanical construction. There were some obvious differences between the sprays, such as the spray being more prone to 'breaking up' with certain water jet monitors. In addition, the water piping to the left and right hand side monitors follow separate paths from the rear of the vehicle which leads to variability between the outputs of the water jet monitors.
- Variability between vehicles
 - The vehicles are each individually built and as such will have inherent minor variances. In addition, the age of the vehicles

and the unknown maintenance history that will have been applied over their service-lives will lead to further differences. All the vehicles were however serviced on arrival in the UK.

- Environmental – wind, temperature, rain
 - Wind speed and temperature were monitored during pressure testing. The test location was sheltered on each side by building facades and consequently the prevailing weather conditions and wind did not generally appear to affect the results significantly. The weather remained mainly dry; on the few occasions it did rain, it did not appear to affect the testing.
- Operator factors
 - The controls on the water cannon for each water jet monitor are not precise and some variability will have been introduced when aligning the water jet monitor to the target. The positioning and alignment of the vehicle for each test may have had minor differences due to the physical size and manoeuvrability of the vehicles. Furthermore, although where possible the same operators were used, occasionally different staff operated the cannons.
- Pressure measurement system setup (applicable only to pressure tests)
 - The measurement system comprised of a calibrated pressure mat which was mounted onto a polycarbonate sheet and then covered in protective layers of waterproof membranes, as illustrated in Figure 2.

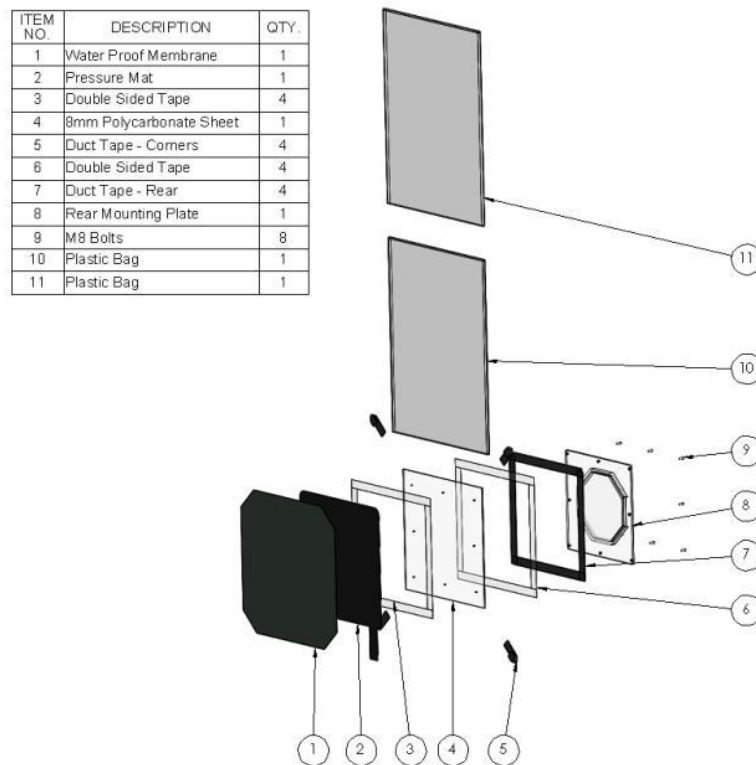


Figure 2 Exploded View of Setup of Pressure Mat

New protective layers were fitted before the start of each day's pressure testing and the pressure mat was removed and dried at the end of each day. Whilst every care was taken to ensure this was done consistently, there is a chance minor variability may have occurred.

The above sources of variability, especially the erratic behaviour of the water jets, can be significant and make the measurements difficult. The issues of water jet variability were encountered by Dstl when they initially characterised the PSNI Somati vehicles in 2002 when it was commented that:

"The measured forces and pressures were very variable; this was principally a consequence of the natural structure of water jets, and the difficulties in directing water jets to small experimental targets".⁹

6.3 Pressure Measurement System

The outputs from the WaWe9 vehicles were characterised by measuring the contact pressures and contact areas, at various distances and water cannon pressure settings. This was then compared with readings similarly obtained for the PSNI Somati measured in June 2014.

⁹ Paragraph 17 – Statement on the medical implications of the use of the Somati RCV9000 Vehicle Mounted Water Cannon – DOMILL – 3rd March 2004

The calibrated pressure mat used, comprises an array of 256 elements in a 16 x 16 grid. The elements are scanned in sequence over a 2 mS period; hence each element is sampled for ~ 8 μ S in each scan period. Each element is 31.75 x 31.75 mm and the mat overall is ~ 0.5 m x 0.5 m. For further details on the pressure mat and the water cannon test rig, see the Appendix in Section 15.

When the PSNI Somati vehicles were tested in 2002, a pressure plate system was used. The calibrated pressure mat offers significant advantages over the use of the pressure plate system, in that it provides a real-time map of the pressure distribution as exemplified by Figure 3.

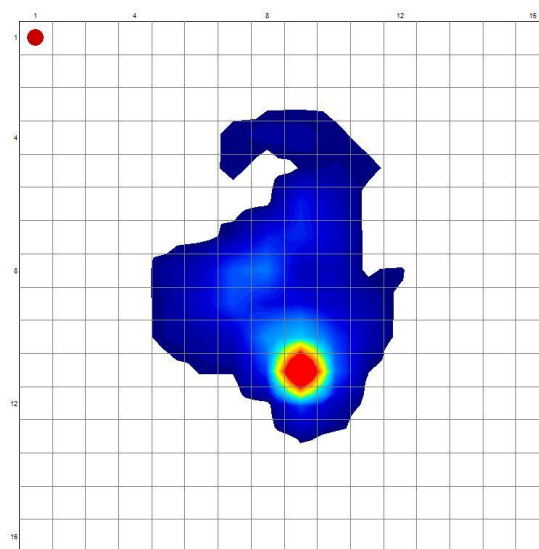


Figure 3 Illustration of Pressure Mat Output (Single Frame)

Furthermore, the system provides a range of analysis options such as identifying the maximum contact area or pressure during a test run. A downside of the system, compared with the simple pressure plate, is that each individual element is necessarily only sampled for 1/256th of the time.

The pressure mat was purchased with a set calibration of 6.89 kPa to 552 kPa. The system can produce readings up to ~ 879 kPa (which is the instrumentation limit) but anything above 552 kPa is outside of the calibrated range. Anything lower than 5.52 kPa is not registered.

Test runs were generally of 20 s duration resulting in 10,000 measurements at each element within the grid.

6.4 Pressure Measurement Terminology

Throughout this report the following terminology is used for the various measured or derived parameters:

- **Frame** – this is one complete scan of the pressure mat
- **Contact area** – the section of the pressure mat, within any individual frame, that is contacted by the water jet with a pressure greater than 5.52 kPa
- **Mean frame contact area** - the average contact area that is observed over a 20 s period (calculated from individual frame contact areas)
- **Maximum frame contact area** – the maximum contact area that is observed over a 20 s period based on a 5 point (10 ms) moving average¹⁰.
- **Frame pressure** – this is the amount of pressure applied to the mat for one frame and is the average of all the elements that are within the contact area
- **Mean frame pressure** – the average pressure that is applied over a 20 s period (calculated from the frame pressures)
- **Maximum frame pressure** – the highest value of pressure observed during the 20 s period based on a 5 point (10 ms) moving average.¹⁰
- **Maximum pressure 3x3, 5x5, 7x7** - the highest value of pressure observed during the 20 s period, based on a 5 point moving average, for areas equating to 3x3, 5x5 or 7x7 elements. These maximum zones can be identified by visual inspection of the pressure maps, or semi-automatically by the measurement system software.¹⁰
- **Frame load** - the total force associated with a single frame i.e. frame pressure x contact area.
- **Mean frame estimated load** – the average frame load (force) measured over a 20 s period.
- **Maximum frame estimated load** – the highest value of frame load (force) observed during the 20 s period, based on a 5 point (10 ms) moving average.¹⁰
- **Maximum frame estimated load 3x3, 5x5, 7x7** – the highest value of frame load (force) observed during the 20 s period, based on a 5 point (10 ms) moving average, for areas equating to 3x3, 5x5 or 7x7 elements.¹⁰

¹⁰ In practice the maximum value from 5 runs each of 20 s was used

6.5 Measurement of Maximum Pressures

Calculation indicates that the maximum continuous pressure that could be sustained by the output of a WaWe9 water jet monitor, if it were wholly directed onto a single element of the mat at zero range, is ~ 690 kPa. This does not happen in practice because there is a minimum achievable range <redacted> over which the jet diverges and also loses momentum.

However, some transient peak pressures (single element, single frame) are observed at this level even at operational distances. An example is shown in Figure 4 (the blue trace) for a 4 s section of a 20 s run.

Note that Figure 4 depicts the peaks in the overall individual frame pressures (i.e. a 16 x16 grid of elements), and that the single element peaks within this can be much higher, exceeding the calibrated range or hitting the instrumented range limit.

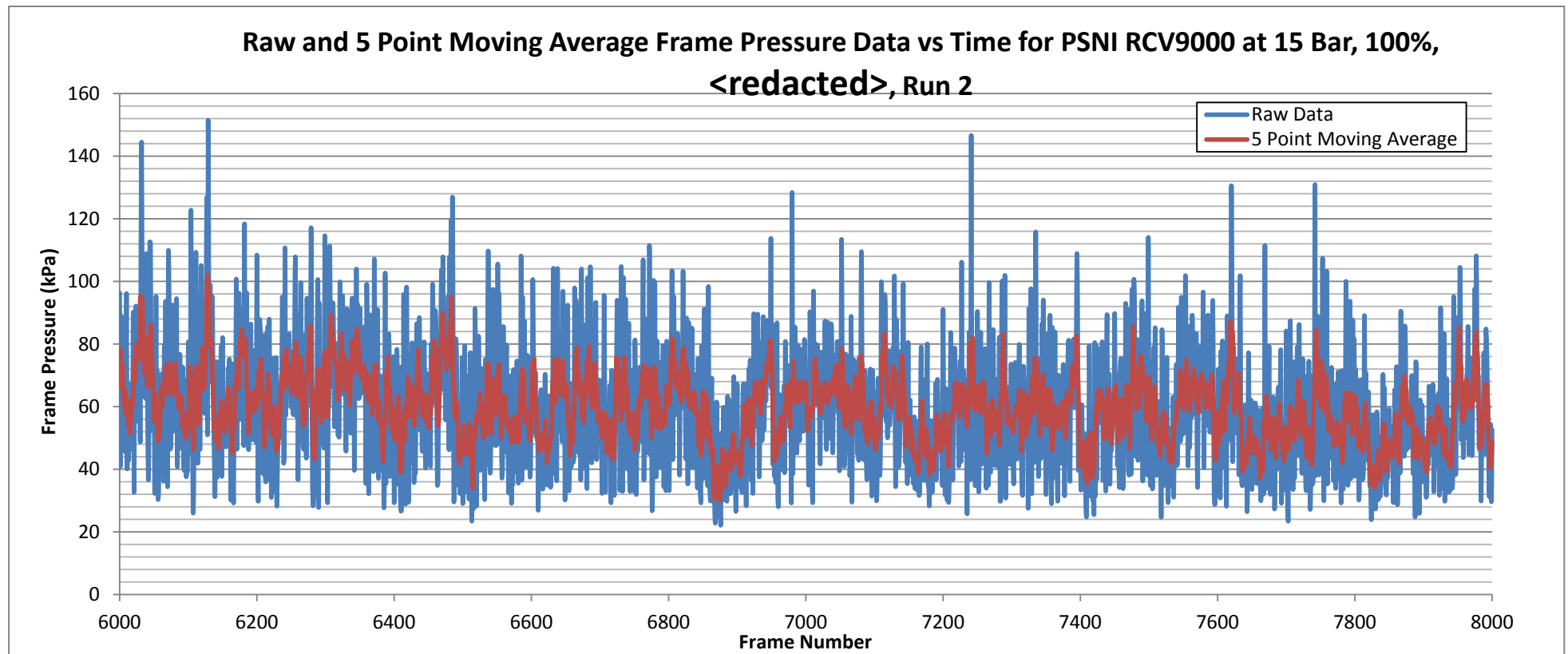


Figure 4 - Illustration of Effect of 5 Point Moving Average on Data.

Single point peaks of this kind represent the “pressure” measured in the $\sim 0.8 \mu\text{s}$ sampling interval. They correspond however to very small amounts of water transferring their momentum to the pressure mat element within the available window, and CAST’s interpretation is that they are a consequence of the chaotic and droplet structure of the jet and unlikely to be meaningful as regards the potential for injury.

To obtain a more helpful view of maximum pressure, CAST has adopted a 5 point moving average approach when processing the data. This corresponds to averaging across a total time interval of $\sim 10 \text{ ms}$ (5 frames), which matches the same averaging period used when the PSNI Somati vehicles were originally assessed by Dstl (though this was a continuous 10 ms window rather than $5 \times 8 \mu\text{s}$ samples over a 10 ms interval). The effect of applying the 5 point average is shown in Figure 4 in the red trace, from which it is immediately evident that the high peak values are not being sustained. This effect of high value single element readings, and hence that of the 5 point moving average, is more pronounced when applied to the 3×3 , 5×5 or 7×7 situation as opposed to the whole 16×16 frame.

It should be further noted that the application of the 5 point moving average, whilst giving a more meaningful view of maximum pressures, does not counter the overall effect of measurement errors associated with very high single element readings. However, the fact that CAST are primarily working on a comparative basis for these trials (i.e. WaWe9 vs. PSNI Somati) mitigates this to a significant degree.

6.6 Assessment of Pressure Measurement Errors

In addition to the calibration, a check was conducted on each day that the pressure mat was used prior to any testing. This daily check was conducted under the standard conditions <redacted> LHS water jet, 12 bar 100% pressure with a full tank of water, and was replicated between 3 and 5 times.

The purpose of these daily checks was to guard against any drift in the measurement system and to provide a basis for assessing overall stability and precision. Note that this does not provide an insight into absolute accuracy, but that is not considered critical in these trials in which CAST are primarily making a comparison between different vehicles and vehicle types. As assurance, before the start of pressure mat testing for each new vehicle, the pressure mat was checked with vehicle <redacted> as this was the first vehicle CAST tested.

The outcome of these results is summarised in Figure 5. It is seen that each vehicle has a different result for this test, as is to be expected. Data taken on the same day are not necessarily independent (they could for example all be affected in the same way by wind factors). CAST has therefore taken the average from each day that vehicle <redacted> was tested and used the sample standard deviation of the resulting 11 day points to estimate the error in the assessment. This reflects the variability in the measurement system itself, plus environmental and operator factors as noted in Section 6.2 above. On this basis the sample standard deviation is 12.3%.

It should be noted that this assessment of error is not applicable to all pressure measurements, but only to those taken over a 20 s period and with a suitable number of replications (generally 5). Its primary use has been to help with presentation of data as described in Section 7.3.1.

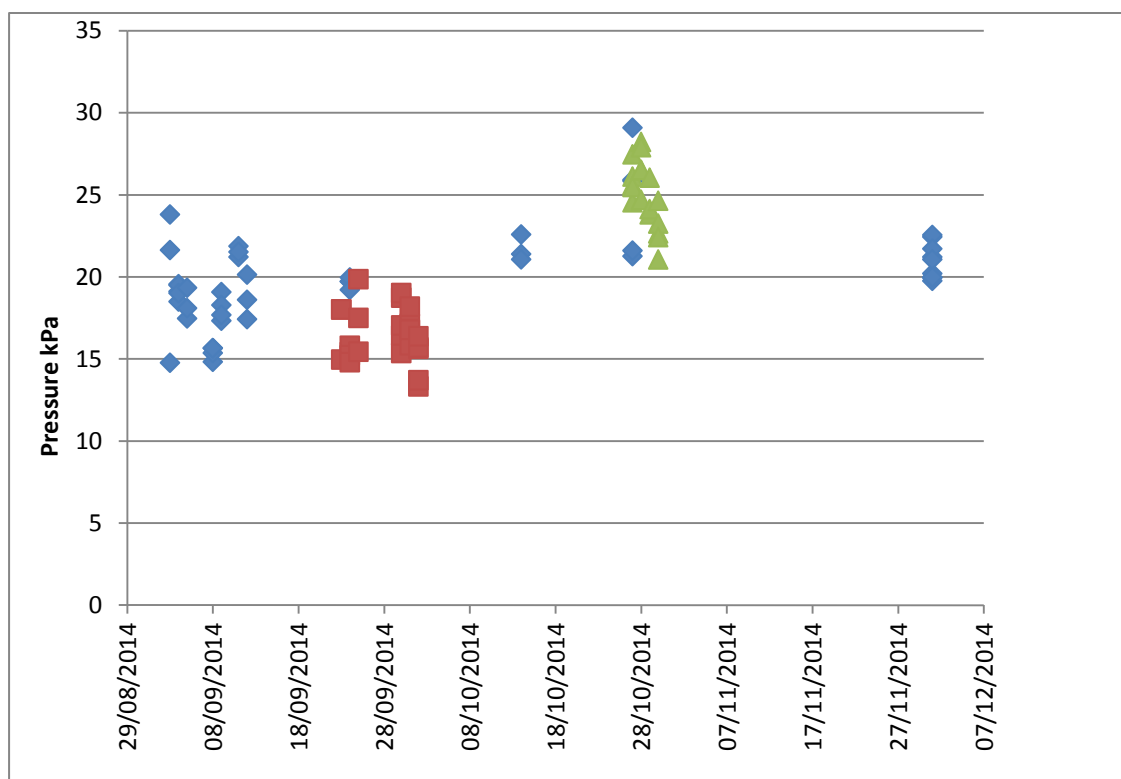


Figure 5 - Graph of Daily Calibration Checks

7. Summary of Trial Results

This section summarises the results of the trials conducted against the test protocol, including the references to the key documentation from which the inspections and tests were derived (see Section 3.1). These references are identified as “TR” (Technical Requirements), “SACMILL” (which includes CAST’s responses), “MPS”, “CoP” or “Advisory”.

7.1 Inspection Results

The following status was applied to the results of each inspection for each vehicle based on CAST opinion:

RED	Red signifies that there is a significant issue that needs to be resolved before overall testing can commence.
AMBER	Amber signifies there are some issues to be resolved prior to testing and / or operational use.
GREEN HATCH	There are comments to be highlighted to MPS or SACMILL.
GREEN	Green signifies that the element of the inspection has no issues.

None of the inspections were assessed as red and therefore, there was no significant issue that needed resolution before the majority testing on any of the vehicles could start.

Inspection checks that were marked amber were communicated to the MPS and their vehicle contractors made efforts to rectify these. There were certain specifics that needed resolution before CAST could complete some of the tests on individual vehicles and CAST returned to MPSTC in early December 2014 to conduct any further tests that were possible at that time.

An inspection report was produced pertaining to each vehicle with detailed results. Table 1 below summarises the status for each vehicle at its inspection date and also the updated status at 2 December 2014, reflecting where rectifications had been carried out. NB there was not a full re-inspection carried out in December; only updates against progress made with rectifications.

A summary of the rectifications that have already been made is included in the Appendix in Section 0. Section 7.1.1 details the remaining outstanding issues that need to be resolved prior to operational use (amber status) and Section 7.1.2 provides relevant comments for highlighting to SACMILL and MPS (green hatch status).

Table 1 - Vehicle Inspections showing Status for Pre-testing and at 2 December 2014

Inspection	Inspection Area	Reference for the Inspection	Inspection Check	Inspection Result Pre Testing			UPDATED STATUS at 2 December 2014		
				Vehicle 1 - 02/09/14	Vehicle 2 - 18/09/14	Vehicle 3 - 24/10/14	Vehicle 1	Vehicle 2	Vehicle 3
VIA	Electrical failure	Advisory	Check effect of total loss of electrical supply to pump engine to ensure that the pump engine shuts down or goes into a mode that does not cause an increase in pressure.						
VIB	<redacted>	Advisory	<redacted>						
VIC	Emergency stop	Advisory	Check that all the emergency stop controls for the pump engine function and the pump is shut down.						
VID	Rear Monitor	SACMILL / MPS	Confirmation of removal of rear monitor, blanking of outlet from pump engine and removal of the controls from the cab.						
VIE	Max Pressure (20 bar)	TR / SACMILL / MPS / CoP	Ensure that all controls that auto select 20 bar are removed and a mechanical stop is installed on the pump engine to prevent the throttle from exceeding a defined point that equates to 16 bar. In addition, ensure that the pump engine cannot be manually increased above 16 bar.						
VIF	Mixing Additives	TR / SACMILL	Confirmation of removal of the control elements on the commander's console and removal of the facility to introduce additives to the pump.						
VIG	Video Cameras	TR / SACMILL / MPS / CoP	Confirm cameras have been installed and are functional. Note the location of all cameras.						
			<redacted>						
			Confirm that cameras have been installed and are functional to monitor the control panels for the commander and the 2 cannoneers.						
VIH	Minimum Distance / Angles	TR / SACMILL / MPS / CoP	Confirm that the angle of the monitors has been adjusted and limited to ensure a minimum contact distance <redacted> for the water jets (<redacted>). Ensure that the range of motion is smooth and that the adjustments have been securely locked off.						

Inspection	Inspection Area	Reference for the Inspection	Inspection Check	Inspection Result Pre Testing			UPDATED STATUS at 2 December 2014		
				Vehicle 1 - 02/09/14	Vehicle 2 - 18/09/14	Vehicle 3 - 24/10/14	Vehicle 1	Vehicle 2	Vehicle 3
VII	PA System	TR / SACMILL / MPS / CoP	Confirm that the system has been installed and the capability of the system (e.g. pre recorded messages).						
VIJ	One Way Valve	TR / MPS	Confirm that there is a one way valve within the fill systems.						
VIK	Pressure Controls	TR / CoP	Confirm that only the commander can control the main pressure available to the water jets.						
			Confirm that each cannoneer has the ability to limit the available pressure they use.						
VIL	<redacted>	TR / SACMILL / MPS / CoP	<redacted>						
VIM	Rear Intercom	TR / SACMILL / CoP	Ensure that the rear intercom is installed and functioning.						
VIN	Signage - English	SACMILL	Ensure that all the signage around the vehicle has been updated to English.						
VIO	Electrical Installation	SACMILL	Confirmation that vehicle has UK certificate.						
VIP	UK Hydrant, Key & Hose	TR / SACMILL / MPS / CoP	Confirmation that appropriate parts are present.						
VIQ	In Cab Inspection	SACMILL / CoP	Ensure that all modifications to the vehicle have not changed visibility from the vehicle, or where applicable they have enhanced the visibility. Take photographs of each of the cannoneers' consoles and the commander's console to enable a check to be made that each of the vehicle's layout is the same. Note any ergonomic features of the cabin.						

7.1.1 Outstanding Issues that Need Resolution (Amber Status)

This section provides more detail on the outstanding issues that need resolution prior to operational use, as identified where the inspections were still marked as amber status at 2 December 2014.

VIE – Max Pressure (20 bar) - “Ensure that all controls that auto select 20 bar are removed and a mechanical stop is installed on the pump engine to prevent the throttle from exceeding a defined point that equates to 16 bar. In addition, ensure that the pump engine cannot be manually increased above 16 bar”

- Vehicle 3 – Controls to select the 20 bar pressure have been removed from the cab. An adequate mechanical stop has been fitted to the pump to physically prevent operation above 16 bar. However, the mechanical stop is not yet sealed; the stop must be sealed and checked it has not been tampered with or adjusted before operational use.

VIF – Mixing Additives - “Confirmation of removal of the control elements on the commander’s console and removal of the facility to introduce additives to the pump”

- Vehicle 1 – The controls within the cab had been blanked off. The switches underneath the blanking plate were still functioning and needed to be removed. This has now been done. However, the connecting pipes should also be removed.

<redacted>VIG – Video Cameras - “Confirm that cameras have been installed and are functional to monitor the control panels for the commander and the 2 cannoneers”

- Vehicle 3 – The cameras had been installed to monitor the commander’s and cannoneers’ panels and were functional, but they need to be fixed securely.

<redacted>VIN – Signage - “Ensure that all the signage around the vehicle has been updated to English”

- All vehicles - Some translated signs still need to be installed. The fuse box and Programmable Logic Controller need to have translated labels fitted. There are also some signs which may need to be translated or if not needed, removed.

7.1.2 Comments Regarding Inspections (Green Hatch Status)

This section provides the comments that were identified in the inspections that CAST believe need highlighting to SACMILL and MPS and where the inspections were therefore marked as green hatch status.

VIH – Minimum Distance / Angles - “Confirm that the angle of the monitors has been adjusted and limited to ensure a minimum contact distance <redacted>for the water jets (<redacted>). Ensure that the range of motion is smooth and that the adjustments have been securely locked off.”

- All vehicles - the adjustments have been made and securely locked off. However, it is recommended that tamper markings are added on each monitor and that these are regularly checked.

VIJ – One Way Valve - “Confirm that there is a one way valve within the fill systems.”

- All vehicles – A one way valve is fitted on the external vehicle inlet. The inlet behind the engine cover has a manual gate valve rather than an automatic one-way valve. It is recommended that filling occurs through the external vehicle inlet only.

<redacted>VIQ – In Cab Inspection - “Ensure that all modifications to the vehicle have not changed visibility from the vehicle, or where applicable they have enhanced the visibility. Take photographs of each of the cannoneers’ consoles and the commander’s console to enable a check to be made that each of the vehicle’s layout is the same. Note any ergonomic features of the cabin”

- All vehicles – the new aluminium trunking that has been installed may pose a hazard to cannoneers (bumping heads). It is recommended that a sponge coating similar to that installed on the roof lights is fitted to remove this hazard.
- All vehicles - Whilst the layouts for the commander’s console and the cannoneers’ consoles were the same across the three vehicles, it should be noted that the driver’s controls in each vehicle did have slight variations.

7.2 Test Results

Table 2 summarises the status of the tests for each vehicle. The following status was applied to the results of each test for each vehicle based on CAST opinion:

Status	Overall Status
RED	The vehicle did not meet the assessment level expected in a substantial way.
AMBER	The vehicle met the assessment in part, but additional actions or mitigation are required.
GREEN HATCH	The vehicle met the assessment level expected, but there are comments to be highlighted to MPS or SACMILL.
GREEN	The vehicle met the assessment level expected.
GREY	This assessment has not been conducted.

Table 2 - Tests with Comments and Results Status

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
A	Minimum Operational Distance	To determine the closest point at which each monitor can hit the centre of the pressure mat at a height of <redacted> from the ground.	TR / SACMILL / MPS / CoP	Minimum distances on each water jet monitor have been adjusted to limit them to be no closer than the RHS water jet on the PSNI Somati. There is a recommendation that tamper markings are applied to angle settings and then these should be regularly inspected by MPS as part of their vehicle checks.			
B	Pressure Measurements	To determine the applied forces/pressures from the water jets using the pressure mat system.	TR / SACMILL / MPS / CoP	See section on pressure measurement results at 7.3.			
C	Maximum Operational Distance	To determine the maximum range at which the water jets can achieve a consistent effect at maximum operational pressure.	TR	Maximum range was determined for each of the water jets on each of the vehicles. <redacted>. MPS to note the effective operational ranges of their vehicles.			
D	Stationary Targets	To test the capability of the water cannon to target multiple stationary objects at various distances and angles.	TR / SACMILL	Overall times were no worse than the PSNI Somati. As the MPS cannoneers became more experienced, there was a noticeable improvement in their times for this test. <redacted>			
E	Static Group	To test the capability of the water cannon to engage a group by direct contact at various distances.	TR / SACMILL / MPS / CoP	Cannoneers were able to quickly engage the first target, then engage each of the next three targets with minimal difficulty. <redacted>Note: The cannoneers improved as they gained experience with the controls. It took longer to target from the further distances, but this was to be expected.			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
F	Moving Target	To test the capability of the water cannon jets to track a target by direct contact at various distances.	TR / SACMILL / MPS / CoP	This test had to be modified post the trials with PSNI. However, comparably the WaWe9 was no worse than the PSNI Somati. <redacted>The revised test demonstrated that the WaWe9 cannoneers were able to track a target moving towards them diagonally and engage at chest height. As the repeats for this test progressed, the cannoneers improved their targeting.			
G	Operation During Hydrant Fill	To determine if operating the water cannon whilst water is being fed into the water tank from a hydrant affects the measured contact forces.	TR / SACMILL / MPS / CoP	All vehicles were able to operate the water jets whilst connected during hydrant fill. The mean frame pressure results showed no noticeable change beyond the variability seen in the daily check data.			
H	Fire Extinguishing System	A visual assessment only will be conducted to determine which areas of the vehicle are covered by the fire extinguishing system (without applying any burning liquid to the vehicle).	TR / CoP	There are 3 sprinklers mounted over the crew cab on each vehicle. There is a deluge system on the front and side windows. The water jets can also rotate round to cover the rear of the vehicle. <redacted>			
I	Public Address System	To determine the level of intelligibility of the voice communication from the water cannon PA system.	TR / SACMILL / MPS / CoP	The Speech Transmission Index (STI) for each vehicle has been calculated from the percentage scores from the single word test conducted and ranges from 0.6 to 1. This result is between good and excellent and is a high standard for a PA system in accordance with IEC 60268-16. Note: MPS to be advised to ensure they are operating within the Control of Noise at Work regulations.			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
J	Audible Reversing System	To determine the ability for public order officers wearing their standard issue public order helmet and “headover” (flame retardant balaclava) to hear the reverse warning siren of the water cannon.	TR / SACMILL / MPS / CoP	The audible reverse warning indicator of the vehicle could be clearly heard by the test subjects at a distance of 1 m. The vehicle also has a visible reverse warning indicator and a reversing camera for the driver in addition to the commander’s rear camera. Note: MPS to be advised to ensure they are operating within the Control of Noise at Work regulations and personnel are trained on working around the vehicle.			
K	External Lighting	To determine the increase in light levels around the vehicle and on a target using any inbuilt lighting on the water cannon.	TR / CoP	There is no additional side or rear lighting (beyond standard vehicle lights) on any of the vehicles. Both water jet monitors have spot lighting and are effective at illuminating <redacted>. There is some variability due to mounting of the spot lights. The cameras all operate in night mode (low light conditions). Note: MPS need to consider operating in low light levels and the cannoneers’ ability to distinguish individuals.			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
L	Clarity of Video Cameras	To determine the ability of the forward facing external cameras to differentiate between people during daylight conditions.	TR / SACMILL / MPS / CoP	Able to see two people at all ranges and distinguish characteristics. However, at greater distances fine detail becomes difficult to determine. The commander's camera was generally better due to the ability to zoom this camera and also having a larger video monitor, compared to the cannoneer's camera which has a fixed focal length and has a smaller video monitor. Note: the water jet monitor cameras are being changed due to the failure of one during testing and the same model no longer being available from the supplier. An alternative camera model has been sourced which has the same or better specification. CAST has advised that limited re-testing needs to be done to ensure there are no material changes in the performance. MPS need to consider the cannoneers' ability to distinguish individuals.			
M	Field of View of Video Cameras	To determine the field of view for each external camera and to give an indication of the limitations in view of the installed cameras.	TR / SACMILL / MPS / CoP	There are some blind spots in the camera coverage of the vehicle, predominantly close against the rear of the vehicle. Note: MPS to be advised to ensure that the vehicle crews and support staff are familiar with any blind spots and manage the risk.			
N	Rear Intercom	To test the audio quality of the external/internal intercom on the vehicle.	TR / SACMILL / CoP	The noise of the pump engine is picked up by the external microphone making it more difficult for speech to be understood inside the vehicle. This had a STI score of 0 - 0.3, which is lower than the 0.6 minimum that should be achieved if possible. Note: MPS to ensure vehicle crews and support staff are aware of the limitation.			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
O	Water Tank Temperature	To check that the water stored in the tank can be maintained at a value greater than 4°C.	TR / SACMILL	Unable to test at the time of year and cannot easily calculate this. There is a water tank heater on the vehicles, but the performance of this is unknown.			
P	Noise Level in Cab	To measure the noise level inside the operators' cabin over a period of 8 hours while the evaluations are occurring.	TR / SACMILL / CoP	<p>The sound levels inside the vehicle did not exceed the Control of Noise at work regulations. However, for the driver and commander seat positions (for extended usage), there is an advisory warning that hearing protection may be required.</p> <p>Note: MPS to consider this issue further and additional work may be required. In addition, the vehicles were not tested on a public highway driving at speed due to the restrictions currently in place over their usage. Further work is advised if the vehicles are permitted to be used on the public highway at operational speeds.</p>			
Q	Temperature in Cab	To measure the operating temperatures in the crew cab during a simulated operational period of 8 hours.	TR / SACMILL / CoP	<p>Only vehicles 1 and 3 have been tested.</p> <p>Note: MPS to consider this issue further and additional work may be required. In addition, the vehicles were not tested on a public highway driving at speed due to the restrictions currently in place over their usage. This should be included within the 8 hour scenario.</p> <p>Vehicle 2 – When CAST returned to conduct this test, the vehicle's was awaiting repair, therefore, it was not possible to conduct the test. CAST to follow up on this.</p>			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
R	Internal Light Levels	To determine the light levels inside the vehicle in both daytime and evening conditions.	TR / SACMILL / CoP	The vehicles all have at least 3 internal lights in the crew cab. The use of these lights does show an increase in light around the crew cab at night. The light levels, or illumination, of the controls specifically was not investigated. Notes: Further work may be required to determine the ability of the crew to use the vehicle in low light conditions. The MPS may have to investigate means to enable the crew to operate effectively at night (e.g. head torches, map reading lights etc.). <redacted>			
S	Operation during Vehicle to Vehicle Fill	To determine if operating on water cannon (WC1) whilst water is being pumped into it from a second water cannon (WC2) affects the measured contact forces.	SACMILL / MPS / CoP	All vehicles were able to operate the water jets whilst filling from a second vehicle. The mean frame pressure results showed no noticeable change beyond the variability seen in the daily check data. Note: The noise levels whilst working at the rear of the donor vehicle need to be assessed against the Control of Noise at work regulation to determine if any hearing protecting is required.			
T	<redacted>	<redacted>	<redacted>	<redacted>			
U	Video Recording of Pressure Selection	The view of the cameras mounted to observe the control switches on the commander's console and cannoneer consoles will be assessed. Ambient light levels will be obtained prior to the assessment.	TR / SACMILL / MPS / CoP	Internal video cameras have been installed to all vehicles and are linked to a single hard drive recorder which also records the video from all external cameras (time and date stamped). Note: MPS need to ensure staff are aware of location of cameras and do not block the view.			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
V	Operation over a Police Protective Carrier (PPC)	To establish if the water cannon is able to function if placed directly behind a standard PPC.	TR / MPS / CoP	The cannoneers could still operate with the vehicle parked behind a MPS public order carrier although their direct vision was obscured and they were reliant on the cameras on the water jet monitors. Note: MPS to be made aware of limitation.			
W	Forward Moving Audible Warning	To test the ability for a public order officer to hear any audible warning that can be generated by the water cannon to inform them that the vehicle is moving forward if required.	TR / SACMILL / MPS / CoP	The forward moving audible warning indicators of the vehicle could be clearly heard by the test subjects at a distance of 1 m. This test included the driver's horn, 'two tones' (all variations) and three tones from the PA system. Note: MPS to ensure they are operating within the Control of Noise at Work regulations.			
X	Effect of Tank Level on Angles	To determine if the angle of the monitors is affected by the level of water in the water tank.	TR / SACMILL	With a full tank of water, the water jets meet the minimum distance requirement. As the tank empties the weight on the rear of the vehicle decreases and this changes the angle of the water jet. An increase in the downwards angle reduces the minimum contact distance. However, this change is approximately 1° which equates to a reduction in minimum contact distance <redacted> The amount of change in angle will be dependent upon the rear suspension of the vehicle. Note: MPS to be advised of this and the cannoneers aware that the minimum contact distance will change with water tank level.			
Y	<redacted>	<redacted>	TR / CoP	<redacted>			
				<redacted>			

Test	Test Area	Assessment	Reference for the Test	Comment	Vehicle 1	Vehicle 2	Vehicle 3
Z	Turning Circle	To determine the turning circle of the water cannon when driven at slow speed (<5mph).	SACMILL	Only 2 vehicles have been assessed to date due to battery failure <redacted>. Both vehicles have a similar turning circle in both directions <redacted> (internal measurement).			
AA	Effects of Water Jets Crossing	To ensure that if 2 water jets from a water cannon meet, the contact forces are not increased.	MPS / CoP	The interaction of the jets does cause a displacement of the original jet from its target. We found no evidence that it significantly increases the mean frame pressure. However, any test involving more than one jet is fundamentally difficult to conduct in a reproducible manner (as noted in Section 7.3).			
AB	Maximum Rotation of the Water Monitors	To determine the maximum rotation for each of the monitors.	MPS	Total maximum rotation of jets is between 260° and 270° Note: MPS to be made aware for training purposes.			
AC	<redacted>	<redacted>	TR / CoP	<redacted>			
AD	Two Water Cannon Jets from Two Vehicles	To determine what happens if two water jets from different vehicles hit the same target at the same time.	SACMILL / MPS / CoP	It is not possible to allocate a status to this assessment (see Section 7.3.2). However, there is no reason why this should be any different to the PSNI Somati.			

7.3 Test B – Pressure Test Summaries

7.3.1 Presentation of Comparative WaWe9 and PSNI Data

The primary aim of the pressure testing is to make a comparison between the recently purchased WaWe9 vehicles and the PSNI Somati vehicles for which there is operational history within the Northern Ireland. The pressure measurements are difficult for the reasons outlined in Sections 6.2 to 6.6 (principally the way in which the jet structure alters), but comparative assessments are somewhat easier than absolute assessments, and any effects due to transient peaks which exceed the calibration range of the pressure mat will, to a first order, be broadly the same for both vehicle types.

Section 7.3.2 summarises the issues and findings for each of the six parameters we have considered, with the Appendix in Section 16 providing tables of results. Where appropriate the data in the Appendix in Section 16 are presented with a “RAG” indicator, where green indicates that the WaWe9 measurement is favourable (as understood by CAST) with respect to the PSNI Somati from the safety perspective. This is not just a question of the observed WaWe9 pressure or load figures being lower, as the limitations of the measurement system have to be taken into account.

Some parameters cannot be directly associated with safety and so are not presented with a RAG indicator. For example, a large mean frame contact area can be regarded as good from the safety perspective in that the jet has diverged (hence peak pressures are likely to be less) but bad when one considers its contribution to frame load.

The measurements presented within this section cover the worst case conditions i.e. the highest allowable pressure settings (16 bar and 100%) and the minimum target range <redacted>

It should be noted that the WaWe9 cannons have a symmetrical monitor arrangement <redacted>. This means that we are not making the WaWe9 comparison against the true worst case condition for the PSNI Somati, and hence that there is some additional safety margin in hand.

7.3.2 Comparative Pressure Tests

Typically 3-4 days of dedicated pressure testing was conducted on each of the three WaWe9 vehicles. For each monitor on each vehicle this comprised:

- 5 runs at pressure settings of 16 bar and 100%, at a range of <redacted> (closest distance and highest pressure).
- 5 runs at pressure settings of 16 bar and 100%, at a range of <redacted>.
- 17 further tests*, each of 5 runs at varying other combinations of pressure settings and range.

In addition, a total of 21 sets of 5 runs were conducted across the 3 vehicles (12 bar, 100%, <redacted>) as part of the daily calibration checks described in Section 6.6.

Access to the PSNI Somati vehicles was limited by operational needs and comprised 1 day on a single vehicle to cover the characterisation of pressures although other

aspects were covered during a 2 day window in 2013. For the LHS water jet monitor, pressure testing comprised:

- 4 runs at 15 bar, 100%, <redacted> (worst case conditions)
- 5 runs at 15 bar, 100%, <redacted>

It should be noted that:

- Each run was of 20 s duration and comprised 10,000 frames of data (see Section 6.3).
- The above numbers exclude tests associated with the PSNI Somati RHS monitor, which was not considered to be functioning properly and was delivering at low pressure. The Somati LHS monitor was therefore used as the basis of all single monitor comparisons.
- The above numbers also exclude tests involving two jets. These tests were difficult to conduct in a meaningful way, partly because of the performance issues with the Somati RHS monitor, but more fundamentally because of the practical difficulty of accurately targeting both jets onto the same point of the pressure mat (the inability to see the points of impact through the very high levels of spray adding a further complication).
- The further tests (denoted *) were specific to the WaWe9 characterisation and do not form part of the comparison. They were included to provide a broader picture of how the vehicles perform under the various settings available to the operators. The results from these tests are presented in Appendix in Section 17.

Analysis of the data from the comparative test runs enables assessment of key parameters (as defined in Section 6.4):

Mean frame pressure is assessed from the means of the 5 x 20 s runs and is presented in Table 16 in the Appendix in Section 16. The RAG indicators are based on the sample standard deviation taken from the daily calibration checks (see section 6.7) such that, for example, dark green indicates that measured values for WaWe9 are greater than 4sd below the PSNI Somati baseline.

CAST found no evidence that the mean frame pressure of the WaWe9 vehicles under maximum pressure settings is greater than the PSNI Somati baseline. This includes consideration of the worst case <redacted> range condition.

Maximum frame pressure measurements represent the overall maximum frame pressure reading occurring within any of 5 x 20 s runs (4 x 20 s runs for PSNI LHS at <redacted>) based on the application of a 5 point moving average (i.e. a ~ 10 ms moving window of 5 x 8 μ s samples). The data are presented in Table 17 in the Appendix in Section 16 (the sample standard deviation of Section 6.6 has no meaning here, so dark green is arbitrarily chosen to indicate that the measured values for WaWe9 are greater than 50% below the PSNI Somati baseline).

Any effects from transient peaks (single element, single frame) which exceed the calibrated range of the pressure mat (~571 kPa) or are clipped by the instrumented range (~879 kPa) are expected to reduce the measured value compared with the true value. The effect will be greater for the larger measured signal (PSNI Somati) and hence will reduce the apparent margin between PSNI Somati and WaWe9. From the safety point of view this means that in the Appendix in Section 16 may be giving a slightly pessimistic picture.

The actual values obtained are expected to reduce if the averaging period (currently 10 ms) is increased.

CAST found no evidence that the maximum frame pressures of the WaWe9 vehicles under maximum pressure settings are greater than the PSNI Somati baseline. This includes consideration of the worst case <redacted> range condition.

Mean frame contact area is assessed from the means of the 5 x 20 s runs and is presented in

Table 18 in the Appendix in Section 16 (RAG status is not applicable here). Contact area includes all parts of the mat where a pressure of 5.52 kPa or greater is registered.

The overall area of the mat, and hence the theoretical maximum contact area is ~ 2500 cm². The theoretical maximum values obtainable for the 3x3, 5x5 and 7x7 areas are ~ 91, 252 and 494 cm² respectively.

The WaWe9 mean frame contact areas are quite variable from monitor to monitor but overall comparable to the PSNI Somati. The variability between monitors emphasises the importance of operators being familiar with the specific monitor they are using, and increasing from a low pressure until they achieve the effect they need.

Maximum frame contact area measurements represent the maximum contact areas occurring within any of 5 x 20 s runs (4 x 20 s runs for PSNI LHS at <redacted>) based on the application of a 5 point moving average (i.e. a ~ 10 ms moving window of 5 x 8 μs). They are shown in Table 19 in the Appendix in Section 16 (RAG status is not applicable).

The theoretical maximum values obtainable for the 3x3, 5x5 and 7x7 areas are ~ 91, 252 and 494 cm² respectively. Almost invariably the maximum figures observed are at or close to these limits, and the data have not been included in the table as they add little or no value.

The maximum areas recorded for WaWe9 are variable and broadly comparable to those for PSNI Somati.

Mean frame estimated load calculations represent the means of 5 x 20 s runs (4 x 20 s runs for PSNI LHS at <redacted>) and are summarised in Table 20 in the Appendix in Section 16 (dark green indicates that the measurements for WaWe9 are more than 4sd below the PSNI Somati baseline).

The pressure mat system estimates load for each frame by multiplying the pressure for each element by the element area, and then summing. The sample standard

deviation used for the RAG system is the same as for pressure previously. This is on the basis that the area of each element is well-defined and that measurement uncertainty is primarily associated with the measurement of pressure.

The <redacted> RHS monitor, and the <redacted> LHS monitor are showing higher mean frame estimated loads at <redacted> which is anomalous (barring the effects of wind). Measurement error and variability in monitor performance over time are probably the main causes of this and it was also noted during the testing of the <redacted> RHS monitor at <redacted> (but not when testing at <redacted>) that the pump did not stabilise at 16 bar but ‘cycled’ between 14 and 18 bar.

Notwithstanding some of the RAG status for the vehicle <redacted> LHS monitor, CAST found no clear evidence that the mean frame estimated loads of the WaWe9 vehicles under maximum pressure settings are greater than the PSNI Somati baseline. This includes consideration of the worst case <redacted> range condition.

Maximum frame estimated load calculations represent the highest value in any of 5 x 20 s runs (4 x 20 s runs for PSNI LHS at <redacted>) based on the application of a 5 point moving average (i.e. a ~ 10 ms moving window of 5 x 8 μ s). The pressure mat system estimates load for each frame by multiplying the pressure for each element by the element area, and then summing. The data are presented in Table 21 in the Appendix in Section 16 (dark green indicates that the measurement values for WaWe9 are more than 50% below the PSNI Somati baseline).

CAST found no evidence that the maximum frame estimated loads of the WaWe9 vehicles under maximum pressure settings are greater than the PSNI Somati baseline. This includes consideration of the worst case <redacted> range condition.

7.3.3 Summary of Test B Pressure Testing

The measurements of pressures and loads have been challenging to make, primarily because of the changing structure within the water jets, and also because of the difficulties of accurately placing two jets onto the same target. CAST have also had to take a view on how best to consider the transient peaks that the measurement system has detected, some of which are outside of its calibration or instrumented ranges. Some apparently anomalous results were obtained when comparing the loads for two of the monitors at <redacted> versus <redacted> and various possible explanations are being considered.

The overall picture, when comparing on a single monitor basis, is that CAST found no evidence that the WaWe9 pressures and loads are greater than the PSNI Somati baseline.

Further support for this position with regard to pressure can be inferred from the results of Test C where measured values for maximum operational distance are between <redacted> and <redacted> for WaWe9 than they are for PSNI Somati.

Experimental and other difficulties have prevented reliable measurements from being achieved in the ‘both’ jets scenarios. However, given that both vehicle types supply pressure independently to both monitors, it is reasonable to read the single monitor comparison across to the “both” situation with confidence.

Variability between monitors (e.g. frame contact areas) can be significant and it is important that operators are familiar with the specific monitor they are using, and operate initially from a low pressure setting working upwards until they achieve the effect they need.

CAST is conscious that the PSNI baseline comprises a single vehicle and in effect a single monitor, and it may be prudent to extend the baseline data set in the future using more PSNI Somati vehicles. In addition, brief repeat testing at PSNI would enable the stability of the measurement system to be verified, although we already have good evidence over a 3 month period of testing the WaWe9.

8. Comparison of Results to SACMILL Recommendations and Technical Requirements

CAST has summarised the results against the two main reference documents for the development of the tests and inspections; SACMILL's recommendations from their interim statement and the Technical Requirements.

As before, a status is given as an assessment against the recommendations and technical requirements, as detailed below:

Status	Overall Status
RED	The vehicle did not meet the assessment level expected in a substantial way.
AMBER	The vehicle met the assessment in part, but additional actions or mitigation are required.
GREEN HATCH	The vehicle met the assessment level expected, but there are comments to be highlighted to MPS or SACMILL.
GREEN	The vehicle met the assessment level expected.
GREY	This assessment has not been conducted.

8.1 SACMILL Recommendations

CAST provided a response¹¹ to the recommendations from SACMILL's Interim Statement on water cannon – November 2013¹² after an initial visit to Germany in May 2014, where CAST did some limited testing and gathered further information.

The recommendations below are the ones that feature technical elements and for which CAST provided a response in their report on the Germany visit. The sections below show the updates to these following the trials. SACMILL's recommendation is included in quotes in the sections below.

¹¹ WaWe9 - Comments against SACMILL Recommendations v3.0 2014-06-06

¹² SACMILL - 2013_11_18 Final Interim Statement WaWe 9_R

8.1.1 Recommendation Paragraph 18

“The peak forces and pressures developed by the WaWe 9 primary water cannon jets should be measured over a range of target engagement distances and at various pump pressure settings. These should be compared with equivalent measurements made on the in-service Somati RCV 9000 water cannon jets. The force and pressure measurements should be obtained using a range of appropriate force plate sizes. SACMILL has reviewed a draft outline proposal for the force and pressure testing of the WaWe 9 water cannon jets and looks forward to reviewing the final detailed technical plan when this becomes available.”

Status & Comment	See section on pressure measurement results at 7.3
Inspection / Test Ref	VIE / B

The mechanical stop has been set such that when pumping 16 bar can be reached, by either one, or both, jets. The 20 bar and +/- controls to manually increase / decrease pressure have been removed from the commander's control panel, with the 16, 12, 8 and 4 bar selection controls being retained. It is necessary to retain the +/- controls that are located in the rear pump engine compartment, for the purpose of vehicle to vehicle filling. However, these can only be used with the rear compartment open which is internally locked from inside the vehicle and also requires the use of a special key to open. The mechanical stop still prevents the pump engine from reaching 20 bar. Any vehicle that would be engaging the crowd would not have its rear compartment open in an operational situation so therefore these controls would not be accessible in operational use.

8.1.2 Recommendation Paragraph 19

“Any substantive differences in performance between the Somati and WaWe 9 water cannon systems should be addressed by a combination of modifications to the WaWe 9 vehicles and implementation of appropriate training, tactics, techniques and procedures.”

Table 3 below details the specific technical differences that were identified to date and their current status after the trials:

Table 3 - Specific Differences Noted between the PSNI Somati RCV9000 and the WaWe9

Number & RAG Status	Difference	CAST Comment – Pre-trial (per CAST’s response to the recommendations from SACMILL’s Interim Statement ¹³)	CAST Comments Post-Trial	Inspection / Test Ref
1	The selected pump pressures on the WaWe9 are selectable to 20 bar compared to 15 bar on the PSNI Somati RCV9000.	From the testing conducted it has been determined that by limiting the pump pressure on the WaWe9 to 16 bar the contact forces and pressures are less than, or similar to, the PSNI Somati WC. See section 8.1.1.	See Section 7.3 on pressure measurement results at	VIE / B
2	The closest forward contact distance on the WaWe9 is less than the PSNI Somati <redacted>RCV9000	The minimum angle that the water jets can be set to will be limited on the WaWe9 <redacted>, See section 8.1.3.	Minimum angles have been set <redacted>. However, it is recommended that an anti-tamper marking is added and regularly checked to ensure no adjustment has been made.	VIH / A / X

¹³ WaWe9 - Comments against SACMILL Recommendations v3.0 2014-06-06

Number & RAG Status	Difference	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹³)	CAST Comments Post-Trial	Inspection / Test Ref
3	The WaWe9 does not have a capability to operate in diffused mode.	The Germans have an operational tactic which creates this effect. However, the Water Cannon Project Board has determined that as the WaWe9 does not have this function, the tactic will not be employed, and is therefore not included in any training, in respect of use of water cannon in England and Wales.	Confirmed that the tactic will not be used by the MPS (see section 8.1.6). The Germans emulate an indirect mode using a developed tactic which the MPS could also consider.	N/A
4	The water jets do not have their own cameras.	It is planned that a camera system is to be installed once the vehicles are in the UK.	Water jet cameras were installed on all vehicles. However, a decision has been made by the MPS to change the cameras, so limited re-testing may be required. The expectation is that the new cameras are the same as or better than those originally fitted.	VIG
5	The cannoneers' chairs rotate with the water jets on the WaWe9, but not on the PSNI Somati RCV 9000.	This is of potential benefit as the cannoneers are always pointing in the same direction as the water jets that they are controlling. Will need to be considered if this affects the training of the operators.	N/A	N/A

Number & RAG Status	Difference	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹³)	CAST Comments Post-Trial	Inspection / Test Ref
6	<redacted>	<redacted>	Observations from the cannoneers support the statement that the WaWe9 is comparable to or better than the PSNI Somati. Test results support this.	D / E / F
7	All the labelling is in German on the WaWe9.	All the labelling will need changing to English.	Some labelling remains to be changed.	VIN
8	The WaWe9 has a rear water jet.	This is being removed and the controls disabled. See section 8.1.6.	Confirmed removed.	VID
9	<redacted>	<redacted>	N/A	N/A
10	Run flat tyres on the WaWe9 are currently fitted and allow 30km travelling distance at maximum speed of 30 km / hr.	Currently unknown what is on the PSNI Somati WC, (CAST to follow up).	PSNI also have run flat tyres (limited speed / distance).	N/A

Table 4 below shows the modifications proposed by MPS and their status after the trials:

Table 4 - Proposed Modifications by MPS to WaWe9

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST’s response to the recommendations from SACMILL’s Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
1	The vehicle will undergo a goods vehicle type MOT test prior to UK registration which will check compliance for items such as; Exterior lighting i.e. dip to left etc, marker lights conforming to UK lighting regulations etc; Brake efficiency to achieve a minimum of 50% for the service brake (foot brake), 25% for the secondary brake (emergency system) and 12% for the parking brake (hand brake); Vehicle tyres; Vehicle emissions i.e. Euro 4; Tachograph reading in MPH as main scale; UK type number plates - currently non age specific; Spray suppression mud flaps; In cab height indicator.	Cannot comment on this as it is outside of CAST’s technical scope.	Vehicles are currently waiting for V5 documents before MOT and Vehicle Emissions certificates can be issued.	N/A

¹⁴ WaWe9 - Comments against SACMILL Recommendations v3.0 2014-06-06

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
2	Compliance to NICEIC regulations together with an electrical installation certificate for 230 volts - involve changing mains plugs to EN60309 standard and external cables.	Cannot comment on this as it is outside of CAST's technical scope. However these changes are essential to ensure that the tank heater will operate when the vehicle is stored.	There are no 230 Vac components on the vehicles themselves. There are separate battery chargers suitable for keeping the charge that should enable the tank heater to operate. However, it was not possible to test this due to environmental conditions at the time of the trials.	VIO / O
3	Installation of UK specification blue lights and siren.	Cannot comment on this as it is outside of CAST's technical scope.	N/A	N/A
4	Fit reversing warning system and reversing camera with night time override.	This will be evaluated as part of the final testing.	The reversing warning and camera system has been fitted. NOTE: MPS to ensure use of these systems is covered in the driver training.	VIG / J
5	Fit blind spot camera system including side cameras and reversing camera with display for driver.	This will be evaluated as part of the final testing.	Standard vehicle blind spot camera system has been fitted. Minimal blind spots remain – MPS to become familiar with location of these.	VIG

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
6	Fit ruggedized IP rated fixed focal length camera system to water jets including individual view screens for each cannoneer, front mounted rotate pan and tilt variable zoom camera with controller at the commander's seat position and rear wide angled camera, all cameras to be viewable (if selected) from the commander's seat. All video feeds to be recorded, solid state hard drive spec to be finalised.	This will be evaluated as part of the final testing. In addition CAST will review the technical specification once available prior to installation.	Cameras fitted and video feeds can be recorded.	VIG / U
7	Installation of up rated public address system – specification to be finalised but will be equivalent <redacted>	This will be evaluated as part of the final testing. In addition CAST will review the technical specification once available prior to installation.	PA system installed on each vehicle.	VII / I
8	Spray vehicle - colour to be advised.	Cannot comment on this as it is outside of CAST's technical scope.	N/A	N/A
9	Fit half Battenberg livery. Fit orange chevron livery on rear of vehicle. Fit aerial identification marker to roof. MPS markings; Police, tyre pressures etc.	Cannot comment on this as it is outside of CAST's technical scope.	N/A	N/A
10	Change all German labels to read English.	This will be evaluated as part of the final testing.	Some labelling remains to be changed.	VIN

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
11	Supply UK type hydrant adapter and key.	This will be evaluated as part of the final testing.	Not all parts available at inspection, but each vehicle has full kit now.	VIP
12	Install mechanical throttle limiter to pump engine to ensure that pump pressure cannot exceed 16 bar.	This will be evaluated as part of the final testing. In addition CAST will review the technical specification prior to installation.	Vehicle 3 needs tamper seal fitting. Vehicles 1 & 2 are green.	VIE / B
13	Removal of 20 bar pressure switch, additives mixture controls, rear water jet control from commander's control console and blanking of these.	This will be evaluated as part of the final testing.	All complete except Vehicle 1 – connecting pipes for the additive system needs removing and Vehicle 3 needs tamper seal on the mechanical stop for the pressure limiter.	VID / VIE / VIF
14	Removal of rear water jet and blanking of water outlet from pump engine to prevent use.	This will be evaluated as part of the final testing. After reviewing the WaWe9 this is achievable.	Removed on all vehicles.	VID

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
15	Modify the lower angle for the two forward facing water jets.	This will be evaluated as part of the final testing. On inspection of the WaWe9 this is achieved by adjustment of a micro switch and is achievable without significant effort. See section 8.1.3.	Lower angles have been modified, and adjustments secured, but anti-tamper markings should be added to the adjustments and be regularly checked. MPS to ensure this is checked as part of the routine checks / maintenance.	VIH / A / X
16	Modification to exhaust system in compliance with emission regulations (London Low emission zone).	Cannot comment on this as it is outside of CAST's technical scope. However these changes must be completed before any further testing is conducted on the vehicles.	N/A	N/A

Number & RAG Status	Proposed Modification	CAST Comment – Pre-trial (per CAST's response to the recommendations from SACMILL's Interim Statement ¹⁴)	Comments Post-Trial	Inspection / Test Ref
17	Installation of a 'black box' recorder to record the pressure selected by the commander and also the pressures selected by the cannoneers.	It could be feasible to install a recording system to record the pressure selected by the commander (direct link from the digital pressure gauge on the commander's control console). In addition it should be possible to record the pressure selected by the cannoneers on separate channels. This would provide an audit of pressure selected. By time/date linking this to the video recording from the water jet cameras and the commander's cameras, this would give an audit trail for pressure used and duration of spray. This cannot be designed and assessed until the vehicles are in the possession of the MPS.	Video cameras installed which provide direct view of commander and cannoneers' consoles with all video recorded on a single hard drive system. This hard drive also records all external cameras. NOTE: MPS need to ensure staff are aware of location of cameras and do not block the view. The commander has ability to see what the cannoneers' see on the commander monitor. There is also no audio recording.	VIG / U

8.1.3 Recommendation Paragraph 20

“The water jets produced by the WaWe 9 are capable of engaging people at considerably closer distances (and potentially with greater force) than those produced by the Somati RCV 9000. Since close proximity to the jets is likely to increase the risk and severity of injury, it is recommended that the implications of this design difference are thoroughly characterised and understood.”

Status & Comment	Minimum angles adjusted to allow minimum distances to be greater than or equal to <redacted> water jet on the PSNI Somati. Lower angles have been modified, and adjustments secured, but anti-tamper markings should be added to the adjustments and be regularly checked
Inspection / Test Ref	VIH / A / X

8.1.4 Recommendation Paragraph 21

“Some general characteristics of the WaWe9 vehicle itself should be established and compared to the Somati model. These include: determining the areas of restricted visibility from the cab, the turning circle, stopping distance of the vehicles in dry and wet conditions, and the effectiveness of any physical countermeasures designed to impede the ability of protesters to climb onto the vehicles.”

In conjunction with the substantive differences already noted (see Section 8.1.1, Table 3) and also the planned modifications (see Section 8.1.1, Table 4), some general characteristics of the WaWe9 were noted during the Germany visit in response to this recommendation. The further information and observations gathered and current status after UK vehicle modifications, inspections and tests are outlined in Table 5 below:

Table 5 – General Characteristics of the WaWe9

Observation	Inspection / Test Ref	Status & Comment
The area around the front of the cab (driver's and commander's view) is covered by 4 blind spot mirrors, which enables the driver and commander to see directly in front of, and down the sides of, the vehicle. The front windscreen has three wiper blades attached to motors at the bottom of the screen, at rest these wipers sit vertically.	VIG / M	UK vehicle cameras fitted - additional cameras have been mounted to allow side and rear views for the commander as well as the driver.
The “A” pillar at each side of the screen causes a certain amount of obstruction of vision to both the driver and commander when seated, however, with slight movement of the head it is possible to see round this for the driver and the commander has the ability to move further if required.	VIQ	No change.

Observation	Inspection / Test Ref	Status & Comment
The turning circle of the vehicle according to the original vehicle specifications is 18.4 m. A quick test was conducted whilst in Germany using one of the water cannons and the turning circle was approximately 21 m. The vehicle specification of the turning circle is probably calculated from the vehicle's dimensions; in addition, the speed at which the turn was conducted may affect the measured value that CAST obtained.	Z	Turning circle has been measured on 2 out of the 3 vehicles, due to limitations of space at the testing site. Inside turning circle was measured, but fits with the outer turning circle limits as identified in Germany.
The stopping distances of the vehicles in varying conditions were not assessed. However, as part of the vehicle licensing requirements the effectiveness of the brakes will be tested.	N/A	N/A – to be covered by vehicle licensing requirements.
<redacted>	<redacted>	<redacted>

8.1.5 Recommendation Paragraph 22

“The public address system of the WaWe 9 should be of comparable efficiency to, or better than, that of the Somati RCV 9000. This system is used to warn of the imminent use of water cannon and hence provides an opportunity for people to disperse voluntarily.”

Status & Comment	Results of testing demonstrate a high level of clarity when communicating via the PA system. MPS to be advised to ensure they are operating within the Control of Noise at Work regulations.
Inspection / Test Ref	VII / I

8.1.6 Recommendation Paragraph 23

“The peak forces and pressures developed by the WaWe 9 rear-mounted water cannon jet should be measured to provide an indication of the effects of this facility (which is absent from the Somati RCV 9000) and its operational role should be clarified.”

Note: It is CAST's understanding that the Water Cannon Project Board has decided to remove use of the rear water jet completely, in line with current operational guidelines.

Status & Comment	Confirmed during inspections that rear water jet has been removed, the outlet from the pump engine has been blanked off and the control system has been removed from the commander's console.
Inspection / Test Ref	VID

8.1.7 Recommendation Paragraph 29

“Consideration should be given to the ergonomics of the operating area, the working conditions of the crew and to the risk of injuring police officers standing close to the device when it is operated.”

The UK team conducted a visual assessment whilst in Germany and their observations were noted. The further information and observations gathered and current status against these after UK vehicle modifications, inspections and tests are outlined in Table 6 below:

Table 6 - Visual Assessment of WaWe9

Observation	Inspection / Test Ref	Status & Comment
The driver's seat has range of motion to improve comfort of driving position and is air sprung. The seat has a standard 3 point seat belt.	VIQ	No change.
The commander seat has range of motion and is air sprung. In addition it has arm rests on both sides. The seat has a standard 3 point seat belt.	VIQ	No change.
The loggists' seat sits slightly higher than the driver and commander seats and has slightly limited leg room, although when tried this was not seen as an issue. This seat has a body harness style seat belt.	VIQ	Installation of central video monitor may restrict some of the original space and view for the loggist.
The cannoneers' seats have a full range of motion to aid comfort and have integrated 3 point seat belts. In addition, they have arm rests on both sides. All seats have adjustable head rests.	VIQ	Installation of video monitors has reduced the range of adjustment due to the potential interface with the vehicle body.
There are air blowers for hot and cold air around the cab, which are controlled from the driver's seat.	VIQ / Q	Temperatures recorded in the cab during warm weather exceeded the ideal temperature maximum of no higher than 25° C.
There is an air conditioning unit at the rear of the cab. However, the effectiveness of this unit is unknown.	VIQ / Q	Temperatures recorded in the cab during warm weather exceeded the ideal temperature maximum of no higher than 25° C.
<redacted>		<redacted>
There is internal lighting – one light at the front of the cab and one on each side of the cab. There is a map reading light by the commander seat.	VIQ / R	There is internal lighting which does increase the light level in the cab, but this has not been assessed operationally.
The windows are opened manually.	VIQ	No change.
The noise level in the crew cab whilst the vehicle/pump engines are operating was acceptable. However, this will be evaluated fully in the final testing.	P	NOTE: MPS are advised to conduct further tests once the vehicle is permitted to drive on the public highway.

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Observation	Inspection / Test Ref	Status & Comment
There is a windscreen washer fluid container inside the cab.	VIQ	No change.
The cannoneers' control panels adjust for height and tilt. Their chairs rotate with the water jet that they are controlling. <redacted>	VIQ / D / E / F	The video monitors have been fitted to the cannoneers' consoles and these restrict some of the potential adjustments for the chairs. Feedback from MPS cannoneers is that the WaWe9 vehicle controls are no worse than on the Somati.
There is a rear view window for each cannoneer but the view is only straight ahead across the roof of the vehicle.	VIQ	No change.
It is planned that the vehicles will be modified with the inclusion of view screens for the commander, the driver and the cannoneers. This should reduce the risk of injuring police officers standing close to the device when it is operated, by increasing the crew's visibility of them.	VIQ / M	Side and rear mounted cameras have also been fitted for the commander as well as the driver. NOTE: MPS needs to ensure than the commander is conversant with the operation of the video system.
The planned modifications may alter the internal layout of the vehicle, so the layout and usability of the vehicle will need to be reassessed during the final testing.	VIQ	The video monitors have been fitted to the cannoneers' consoles and these restrict some of the limitations to potential adjustments. Additional equipment has been fitted inside the vehicle and this has also reduced the space originally available e.g. commander's video monitor, PA system, video control panel.

8.2 Technical Requirements

The table below contains the list of technical requirements, based on the WC Operating Requirements v2.0 as signed by CC Ian Learmonth. These have been defined as essential, highly desirable or desirable for the purchase of an interim option.

These technical requirements exclude any requirement which is in relation to the mechanical aspects of the vehicle (e.g. turning circle) or operational usage.

Table 7 below shows the Essential Requirements for the Interim Option along with the assessment RAG Status and comments.

Table 7 - Essential Requirements with Comment and Status

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-4	The water cannon must be usable in night time conditions with no street lighting (0.27–1.0 lux ^{15,16}).	Essential	K & R	Cameras have low light capability enabling the crew to see at night using the video facilities. The water monitors have spot lights attached to them which are linked to the direction of the water jet. The increase in light level from these enabled the cannoneers to see a target at <redacted>			
WC-TR-5	The water cannon must be usable in twilight conditions (100 lux ³).	Essential	K & R	There were no issues with using the vehicles at twilight.			

¹⁵ Lux = unit of illuminance, equal to one lumen per square meterK

¹⁶ Paul Schlyter, [Radiometry and photometry in astronomy FAQ](#) (2006)

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-6	The water cannon must be usable in daytime, low light conditions (1,000 lux ³).	Essential	K & R	There were no issues with using the vehicles in low light conditions in the daytime.			
WC-TR-7	The water cannon must be usable in daylight, bright sunshine conditions (10,000–25,000 lux ³).	Essential	K & R	The sensors on the cameras on the water jet monitors can become overloaded in bright light conditions (e.g. direct / reflected sunlight) resulting in low image quality on the video monitors. Note: MPS to ensure cannoneers are aware of potential issues and consideration to being able to see clearly.			
WC-TR-9	<redacted>	<redacted>	T	<redacted>			
WC-TR-12	The water cannon shall have a one way valve on the filling system to ensure that it does not contaminate the water supply network.	Essential	VIJ	A one way valve is fitted on the external vehicle inlet. The inlet behind the engine cover has a manual gate valve rather than an automatic one-way valve. It is recommended that filling occurs through the external vehicle inlet only.			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-13	The indicated water pump pressure of the water cannon must be adjustable to provide a range of pressures to enable the measured force on contact of each jet to be equivalent to the PSNI Somati 9000 water cannon.	Difficult to measure actual pressure at pump due to access	B	Pressures of 4, 8, 12 and 16 bar selectable by the commander with cannoneer control of 20, 40, 60, 80 and 100%.			
WC-TR-14	The main water pump pressure that is available to all monitors must be controllable from the commanders position only.	Essential	VIK	It is confirmed that the main water pump pressure is controllable from the commander's position only.			
WC-TR-15	Each monitor must have separate controls to allow the water pressure from the monitor to be controlled by the operator, in addition to those limits on the overall pump pressure set by the commander.	Essential	VIK	Cannoneers' have controls of 20, 40, 60, 80 and 100%.			
WC-TR-16	The output of the water cannon from each forward facing monitor (as a minimum) must be adjustable to provide an indirect spray (rain / shower effect) or a focused spray (direct jet) at all pressures.	Essential	B	There is no indirect spray mode on the WaWe9 vehicles. The Germans emulate an indirect mode using a developed tactic which the MPS could also consider.			
WC-TR-17	The measured contact force/pressure must be equivalent to the contact force/pressure measured by the same system from a Somati water cannon currently in use by PSNI (when measured by CAST's measurement systems).	Essential	VIE / B	The WaWe9 water cannon pressures / forces were no greater than those of the PSNI Somati water cannon. See Section 7.3 on pressure measurement results.			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-32	The water cannon must have an audible reversing warning that can be heard above the noise of the water cannon by an officer wearing their “headover” (flame retardant balaclava) and a standard issue Home Office approved public order helmet. Additionally a reversing camera system is desirable.	Essential	VIG / J	The audible reverse warning indicator of the vehicle could be clearly heard by the test subjects at a distance of 1 m. The vehicle also has a visible reverse warning indicator and a reversing camera for the driver. NOTE: MPS to be advised to ensure they are operating within the Control of Noise at Work regulations.			
WC-TR-43	The temperature of the stored water must be > 4°C.	Essential – need to ascertain how this is achieved.	O	Unable to test at the time of year and cannot easily calculate this. There is a water tank heater on the vehicles, but the performance of this is unknown.			
WC-TR-46	The doors shall be internally locking.	Essential	VIL	All doors on the cab lock internally.			
WC-TR-52	The water cannon shall include a system for extinguishing fires on the external surfaces of the vehicle.	Essential	H	There are 3 sprinklers mounted over the crew cab on each vehicle. There is a deluge system on the front and side windows. The water jets can also rotate round to cover the rear of the vehicle. <redacted>			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-53	The noise level in the cabin must not exceed The Control of Noise at Work Regulations (2005).	Essential – or mitigate via protective equipment	P	<p>The sound levels inside the vehicle did not exceed the Control of Noise at work regulations. However, for the driver and commander seat positions for extended usage, there is an advisory warning that hearing protection <u>may</u> be required.</p> <p>Note: MPS to consider this issue further and additional work may be required. In addition, the vehicles were not tested on a public highway driving at speed due to the restrictions currently in place over their usage. Further work is advised if the vehicles are permitted to be used on the public highway at operational speeds.</p>			

Table 8 below shows the Requirements that needed to be established along with the assessment RAG Status and comments.

Table 8 - Requirements to be Established with Comment and Status

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-18	The forward facing monitors must have a minimum range of <redacted>in direct spray mode and a minimum range of <redacted>in indirect spray mode.	Need to know min. & max. distance	VIH / A, C & X	For direct spray mode: Minimum ranges have been set to no closer than <redacted>Maximum range was determined for each of the water jets on each of the vehicles and ranged from <redacted>. There is no indirect spray mode.			
WC-TR-19	The water jet from each forward facing monitor must be able to target, and maintain position on, a stationary object <redacted>s.	Will test to establish capability	B & D	The stationary target test (D) evidenced that targeting was possible; the pressure testing (B) involved maintaining position on the test rig <redacted>			
WC-TR-21	The water jet from each forward facing monitor must be able to target and sweep (in direct mode) across a stationary group of 5 people standing side by side (2m total width) at a <redacted>	Will test to establish capability	E	Cannoneers were able to quickly engage the first target then sweep across a further three targets.			

Table 9 below shows the Highly Desirable and Desirable Requirements for the Interim Option along with the assessment RAG Status and comments.

Table 9 - Highly Desirable and Desirable Requirements with Comment and Status

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-1	The water cannon shall continue to be operational with no loss of functionality in heavy rain (>1hr, 7.6mm/hr rate, droplet size >5mm) ¹⁷ .	Desirable	N/A	Not tested – However during the rain that did occur the vehicle did not stop working.			
WC-TR-2	The water cannon shall continue to be operational with no loss of functionality with an external recorded temperature of -10°C.	Desirable	N/A	Not tested – No facility to reduce the ambient temperature that low and temperature during the trial months did not drop that low.			
WC-TR-3	The water cannon shall continue to be operational with no loss of functionality with external recorded temperature of +30°C.	Desirable	N/A	Not tested - No facility to increase the ambient temperature that high and temperature during the trial months did not go that high.			
WC-TR-8	The water cannon must enable the trained police operator to be able to target and track, with a water jet, a moving person, <redacted>moving in any direction, at either walking or running speeds.	Desirable	F	WaWe9 cannoneers were able to track a target moving towards them diagonally and engage at chest height. <redacted>			
WC-TR-10	<redacted>	<redacted>	<redacted>	<redacted>			

¹⁷ American Metrological Society (<http://glossary.ametsoc.org/wiki/Rain>)

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-11	<redacted>	<redacted>	<redacted>	<redacted>			
WC-TR-22	The water cannon must be refillable from a standard UK fire hydrant operating at a minimum pressure of 1.5 bar ¹⁸ .	Highly Desirable	VIP / G	All UK parts for hydrant filling present. All vehicles were refillable from the UK fire hydrant.			
WC-TR-26	The water cannon must be able to operate over a long wheel base Protective personnel carrier with a height of 3m.	Desirable	V	The cannoneers could still operate with the vehicle parked behind a MPS Public Order carrier although their direct vision was obscured and they were reliant on the cameras on the water jet monitors.			
WC-TR-28	The water cannon shall be able to remove temporary barricades to the size of a family car and weighing up to 2 tonnes.	Desirable	N/A	Not tested – no capability on the vehicle.			

¹⁸ This is based on the minimum requirements on water companies and is subject to regional variation (<http://www.water.org.uk/home/policy/publications/archive/industry-guidance/national-guidance-document/national-guidance-document-on-water-for-ffg-final.pdf>)

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-29	The water cannon shall have a public address system capable of being intelligible at a distance of <redacted>over the noise of the vehicle. RASTI ¹⁹ level of greater than 0.6 or equivalent test.	Desirable	VII / I	The Speech Transmission Index (STI) for each vehicle has been calculated from the percentage scores from the single word test conducted and ranges from 0.6 to 1. This result is between good and excellent and is a high standard for a PA system in accordance with IEC 60268-16. Note: MPS to be advised to ensure they are operating within the Control of Noise at Work regulations.			
WC-TR-30	The water cannon shall include a system to play up to 50 pre-recorded messages over the public address system.	Desirable	VII	The PA system has a slot for USB / memory stick and SD card to enable pre-recorded messages to be played over the PA.			
WC-TR-31	The water cannon shall include a system to enable the recording and playback of messages for use on the public address system.	Desirable	VII	The installed system cannot record, only playback.			

¹⁹ http://www.isvr.co.uk/spe_hear/comint.htm (RApid Speech Transmission Index RASTI)

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-33	The water cannon must have a selectable audible warning system to indicate that the vehicle is moving and that can be heard above the noise of the water cannon by an officer wearing a headover and a standard issue Home Office approved public order helmet.	Desirable	W	The forward moving audible warning indicators of the vehicle could be clearly heard by the test subjects at a distance of 1 m. This test included the driver's horn, 'two tones' (all variations) and three tones from the PA system. Note: MPS to be advised to ensure they are operating within the Control of Noise at Work regulations.			
WC-TR-34	DOT Matrix display capable of displaying a minimum of 100 characters and readable at 30m in lighting conditions specified in TR4 to TR7.	Desirable	N/A	There are no dot matrix displays on the water cannon vehicles.			
WC-TR-35	The water cannon shall record all uses, including date, time, duration and output pressure for each monitor.	Desirable – need to understand limitations	VIG / U	Video has been installed on commander's and cannoneers' consoles.			
WC-TR-37	The water cannon must have visual and audio recording capability, providing 360° coverage around the vehicle and functional in all lighting conditions (TR4 to TR7) and weather conditions (TR1 to TR3).	Desirable	VIG / L & M	There is no audio recording capability on the water cannon. There are some blind spots in the coverage of the vehicle, predominantly close against the rear of the vehicle.			
WC-TR-38	The water cannon must have independent cameras on each water jet to record usage in all lighting conditions (TR4 to TR7) and weather conditions (TR1 to TR3).	Desirable	VIG / L, M & U	There are independent cameras on each water jet.			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-39	The water cannon shall have a extendable camera system with a working height above the water cannon roof of 2 metres as a minimum, that is functional in all lighting conditions (TR4 to TR7) and weather conditions (TR1 to TR3).	Desirable	N/A	There is no extendable camera system on any of the vehicles.			
WC-TR-40	The water cannon shall have flood lighting connected to the monitors and capable of illuminating an object at a distance <redacted>, at night (WC-TR-4). (Expect light level <redacted> of 320 to 500 lux ²⁰).	Desirable	K	Light levels at target distance not achieved. However, cameras also have low light capability and can provide an image in such conditions.			
WC-TR-41	The water cannon shall have illumination around the vehicle to enable an area of 3 m radius to be illuminated to create a safe working environment as required, to a light level of 320–500 lux ²¹ .	Desirable	K	No illumination around the vehicles other than the headlights.			
WC-TR-42	The water cannon shall include a data link to enable the transmission of video and audio footage in real time to a control centre ²² .	Desirable	N/A	No data link on any of the vehicles.			

²⁰ [Illumination](#)". Regulations (Standards - 29 CFR). Occupational Safety and Health Administration, US Dept. of Labor

²¹ [Illumination](#)". Regulations (Standards - 29 CFR). Occupational Safety and Health Administration, US Dept. of Labor

²² Specification to be defined for long term purchase option

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-44	Each forward facing monitor shall have a range finder linked to the direction that the monitor is pointing in and accurate to within 0.2 m	Desirable	N/A	No range finder on the forward facing monitors on any of the vehicles.			
WC-TR-47	<redacted>	<redacted>	<redacted>	<redacted>			
WC-TR-48	<redacted>	Desirable	AC	<redacted>			
WC-TR-49	<redacted>	Desirable	N/A	<redacted>			
WC-TR-50	The water cannon shall have temperature regulation in the operators area between +15°C to +25°C	Desirable	Q	<p>Only vehicles 1 and 3 have been tested as yet. Vehicle 1 exceeds the 25°C limit specified. Further testing may be required to determine the extent of this problem.</p> <p>Note: MPS to consider this issue further and additional work may be required. In addition, the vehicles were not tested on a public highway driving at speed due to the restrictions currently in place over their usage. This should be included within the 8 hour scenario.</p>			
WC-TR-51		Desirable	Y	<redacted>			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-54	Any intercom system/external communication equipment shall be intelligible in cab using the required equipment (e.g. headset, microphones etc). RASTI level of 0.6 or greater (or equivalent test method)	Desirable	VIM / N	The noise of the pump engine is picked up by the external microphone making it more difficult for speech to be understood inside the vehicle. This had a STI score of 0 - 0.3, which is lower than the 0.6 minimum that should be achieved if possible. The intercom exceeded the 0.6 minimum under all other test criteria. MPS to be made aware.			

Table 10 below shows the Requirements for the Interim Option that were not required or no longer required.

Table 10 - Requirements Not Required or No Longer Required

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-20	<redacted>	Will test to establish capability	N/A	MPS confirmed that they would NOT be emulating indirect spray (diffuse) mode by any other tactical means.			
WC-TR-23	The water cannon must be refillable from an open water source.	Desirable	N/A	MPS confirmed that the water cannon will not be filled from an open water source.			

Unique ID	Technical Requirement (TR)	Interim Option - Purchase	Test / Inspection Ref	Comment	Vehicle 1	Vehicle 2	Vehicle 3
WC-TR-24	The water cannon must be able to filter water taken from an open water source to ensure that no objects >5mm are passed through the filter.	Will test to establish capability	N/A	MPS confirmed that the water cannon will not be filled from an open water source.			
WC-TR-25	The water cannon must be resistant to the effects of salt water.	Desirable	N/A	Not Tested. As MPS confirmed that the water cannon will not be filled from an open water source, it is not expected that salt water will be used with the vehicles.			
WC-TR-27	The water cannon shall be able to mix additives at the point of spray.	Not Required	VIF	Confirmed that the ability to mix additives is NOT required at this time and the facilities to do this has been removed.			
WC-TR-36	The water cannon shall enable the recording of decisions and commands issued.	Desirable	N/A	There is no audio recording capability with the video camera system installed. Therefore the MPS confirmed that a loggist will be on the crew during all operational use.			
WC-TR-45	The water cannon shall have the capability to tackle fires, either directly using the monitors or directly from the water pump via hose reels.	Desirable	N/A	MPS confirmed that they will NOT use the water cannon to tackle fires as their staff are not trained in doing this.			

9. Commentary on Non-Pressure Tests

The vehicles were subjected to an extensive range of tests to determine how they compared with the requirements and recommendations developed for the vehicles.

9.1 Evaluation against the Inspection Criteria

Table 11 shows the results of the inspection on 2nd December 2014. They are predominantly green, with a small number of advisories and amber status. There were no red status from the inspections.

	Vehicle 1	Vehicle 2	Vehicle 3
Green	13	14	12
Green Hatch	4	3	4
Amber	3	3	4
Red	0	0	0

Table 11 Inspection Report Summary as of 2nd December

9.2 Evaluations against the Test Criteria

Table 12 shows the results of the technical testing for each vehicle. There are a number of advisory comments that came from this testing for areas where either additional work is recommended or the MPS need to consider how to mitigate identified issues.

<redacted>

	Vehicle 1	Vehicle 2	Vehicle 3
Green	6	5	6
Green Hatch	13	14	14
Amber	6	4	5
Red	3	3	3

Table 12 Output from Technical Testing Against Protocol

9.3 SACMILL Recommendations

Table 13 Demonstrates that all the SACMILL recommendations have been considered although more work is needed for those with an amber status in CAST opinion.

Paragraph	Green	Green Hatch	Amber	Red
18				
19	2	1	2	0
	7	2	3	0

20		1		
21	2	1	1	0
22		1		
23	1			
29	6	5	4	0

Table 13 - Assessment of Vehicle Against SACMILL Recommendations

9.4 Technical Requirements – Essential

The vehicles have been assessed against the interim technical requirements for vehicle mounted water cannon. These requirements were derived from the technical requirements for vehicle mounted water cannon developed for the purchase of new vehicles. These vehicles were purchased from the German Police as an interim solution to provide water cannon capability in England and Wales. As such they have not met all the technical requirements. The assessment is divided into essential, highly desirable and desirable requirements.

Table 14 provides an overview of the essential requirements.

	Vehicle 1	Vehicle 2	Vehicle 3
Green	7	7	7
Green Hatch	4	5	5
Amber	2	1	1
Red	2	2	2

Table 14 - Technical Requirements - Essential

Each of the vehicles has two essential requirements with red status:

- Capability to work in indirect mode (disperse) – the WaWe9 water cannons purchased do not have this facility though the MPS has stated that they will not be using this tactic.
- <redacted>

9.5 Technical Requirements – Highly Desirable and Desirable

Table 15 shows the assessment of the vehicles against the highly desirable and desirable requirements.

	Vehicle 1	Vehicle 2	Vehicle 3
Green	5	5	5
Green Hatch	3	3	3
Amber	4	4	5
Red	11	10	10

Table 15 - Technical Requirements - Highly Desirable and Desirable

The number of red status is higher than any of the other assessments. This is due to the requirements covering non essential items (such as DOT matrix display, video

link, telescopic video system etc) which were desirable rather than essential in an interim solution and the vehicles do not have some of these features.

10. Observations

CAST's observations during the trials are broken down in the sections below.

10.1 Points for MPS to Mitigate

MPS will need to consider how to mitigate the below observations, by either risk assessment, any further vehicle improvements, training, guidelines for use, operational tactics or combinations thereof.

- <redacted>
- <redacted>
- Whilst the layouts for the commander's console and the cannoneers' consoles were the same across the three vehicles, it should be noted that the driver's controls in each vehicle did have slight variations, and the MPS should ensure that their driver training reflects this (see inspection VIQ).
- Video evidence (pressure monitoring) – training needs to be considered to include good practice for the cannoneers to ensure they do not obscure the view of the camera accidentally with their hands (see Test U).
- A robust maintenance schedule, including regular checks and operation, needs to be put in place, as evidenced by the number of failures on the vehicles throughout the trials period.
- It is recommended that MPS propose mitigations for the lack of self-cleaning facilities on the video cameras (VIG).
- <redacted>
- The sensors on the cameras on the water jet monitors can become overloaded in bright light conditions (e.g. direct / reflected sunlight) resulting in low image quality on the monitors.

10.2 Advisory Points for MPS to Note

There are various advisory points that have been observed during the testing, as outlined below:

- The waterproof housing for each of the water jet monitor cameras on all of the vehicles suffered from condensation. This caused problems with the camera image (fog effect) resulting in the units needing to be dried out to work properly again. The housing has heater elements but these are only functional when the camera system is powered. The MPS need to ensure that this problem is either resolved or is part of the pre deployment checks.
- At the retest pressure testing in December 2014, Vehicle 1 struggled to reach expected pressures at 16 bar (as per the commander's digital pressure display). 12 bar and 8 bar pressures were as expected. This may be indicative of a future problem and should be reviewed by the vehicle maintenance contractor.

- During the course of the trials, as the vehicles are new to the MPS and their vehicle suppliers, CAST's Trials Manager / Technical Lead provided a lot of support and knowledge to help fix the vehicles, or advised on the potential source of the problems, when something went wrong. This type of knowledge needs to be generated within MPS and supports the recommendation that MPS staff become fully familiar with the vehicles themselves, as well as their use in operational scenarios. The absence of supporting vehicle manuals in English did not assist this situation for the MPS, but CAST are aware that the MPS are actively working to get translations of the manuals.
- Ensure that all water cannon staff are familiar with the effects of various pressures of water over varying distances, to aid in the appropriate selection of pressure during operational deployment.
- MPS to note the effective operational ranges of their vehicles. The minimum operational range was set at <redacted> (Test A). The maximum range varied from <redacted> (Test C).
- When using the rear intercom, the speaker from outside of the vehicle is hard to hear within the cab when the pump engine is running (see Test N).
- <redacted>There are 3 sprinklers mounted over the crew cab on each vehicle, a deluge system on the front and side windows and the water jets can also rotate round to cover the rear of the vehicle (Test H).
- <redacted>There is no additional side or rear lighting beyond standard vehicle lights on any of the vehicles (Test K).
- MPS to note the blind spots in the coverage of the vehicle, predominantly close to the rear of the vehicle (Test M).
- The temperature in the cab of vehicle 1 reached over 25°C on the day that it was tested. Further testing is recommended (see Section 11.6) to establish suitable operating parameters and help to mitigate this (Test Q).
- It is possible to operate the water jets from behind a MPS Public Order carrier, but direct vision is obscured and the cannoneers will be reliant upon the cameras on the water jet monitors (Test V).
- If the water jets from the LHS and the RHS cross, then there will be an element of interaction and the overall jet direction and dynamics will change (Test AA).
- As the tank water level changes, there is an effect on the angles of the water jets equating to a difference in the ground contact distance. Cannoneers should be aware of this for targeting purposes (Test X).
- Ensure training of MPS staff includes safe handling of water hoses, use of hydrants and vehicle to vehicle fill options.
- Need to ensure that MPS cannoneers are aware of the horizontal rotation limits of the water jets (Test AB).
- The vehicles are not exactly the same in terms of performance and as such the MPS need to ensure that all water cannon staff are familiar with all vehicles.

10.3 General Observations

The following general observations have also been noted:

- The MPS have now replaced the hoses that were originally supplied with the vehicles with new UK specification hoses.
- There is no audio recording capability with the video camera system installed.
- It was noticeable that the cannoneers improved with experience during the target testing (D, E and F), and this supports the recommendation for the MPS to ensure their staff increase their familiarisation with the vehicles and have regular opportunities to practice and refine their skills.
- MPS need to consider the cannoneers' ability to distinguish individuals, including operating in low light levels.
- It is difficult to see when a water jet contacts an object. However this spray clears quickly once the water jet is stopped. The same effect occurs with the PSNI Somati cannon.
- The MPS cannoneers involved in the testing had been trained on the PSNI Somati water cannons and they gave feedback that they found in general the WaWe9 water cannon controls were more responsive and better aligned than the PSNI Somati controls.
- <redacted>

11. CAST Recommendations

11.1 Vehicle Problems

It is recommended that the remaining vehicle issues that were identified during the inspections are resolved by MPS and are re-inspected by CAST²³:

- Vehicle 1
 - The connecting pipes from the mixing additives capability should be removed (VIF).
 - The remaining German signage needs converting to English, or removing. This includes the fuse box and Programmable Logic Controller that need to have translated labels fitted (VIN).
- Vehicle 2
 - <redacted>
 - The remaining German signage needs converting to English, or removing. This includes the fuse box and Programmable Logic Controller that need to have translated labels fitted (VIN).
- Vehicle 3
 - The mechanical stop on the pump physically preventing operation above 16 bar must be sealed (VIE).
 - The cameras to monitor the commander's and cannoneers' panels need to be fixed securely (VIG).
 - The remaining German signage needs converting to English, or removing. This includes the fuse box and Programmable Logic Controller that need to have translated labels fitted (VIN).
- All Vehicles
 - It is recommended that tamper markings are added to the angle adjustments on each water jet monitor (see inspection VIH).
 - It is recommended that a sponge coating similar to that installed on the roof lights, should be applied to the new aluminium trunking that has been installed in the cab (see inspection VIQ).
 - The deluge jets need realigning to ensure the most effective coverage of the windows for clearing purposes (test Y).
- <redacted><redacted>).

11.2 Vehicle Familiarity

MPS staff should become fully familiar with the vehicles, not just in terms of water jet operation.

- As evidenced during the trials, as the crews became more familiar with the vehicle, they were able to resolve some potential issues themselves. This knowledge will only improve with experience.

²³ Some of these points may have been resolved since CAST's last view of the vehicles

- It was also evident from the testing that the more familiarity the cannoneers had, the better they became with their targeting (see Tests D, E, F).

11.3 Replacement of Parts and Re-testing

Considering the age of the vehicles, it is recommended that CAST work with SACMILL (via the Less Lethal Technology and Systems Strategic Board) and MPS to agree an approach to any re-testing that may be required due to the replacement of parts in the future. This will need to encompass the replacement of like-for-like critical parts and any design changes that are enforced by obsolescence. Any proposal will need to consider the availability of specialist resources, money and time.

There are some vehicle problems found during the trials for which CAST recommends some limited re-testing to confirm satisfactory resolution. These are detailed below:

- Vehicle 3 did not have the engine stop tamper seal fitted before pressure testing (see inspection VIE).
- Vehicle 2 has a broken pressure sensor on the pump engine. This failed after the specific pressure tests on Vehicle 2 had been completed.
- All vehicles - MPS have taken the decision to replace all of the water jet monitor cameras types due to further problems that they found, and these will need to be subject to a partial re-test by CAST, as the camera tests completed involved the old cameras. It is recommended that Test M (Field of View of Video Cameras) is repeated on all new cameras (one was already fitted on vehicle 3 and has been through CAST's testing) and that Test L (Clarity of Video Cameras) is repeated on one of the vehicles.

11.4 Regular Use

It is recommended that the vehicles are regularly used to avoid some of the problems encountered during the trials.

Problems found which regular use would help avoid include:

- Problems with the pump system on some of the vehicles as the vehicles did not have water through them for several weeks whilst they were undergoing modifications.
- The LEZ filters on one of the vehicles got clogged. It was advised by the MPS vehicle maintenance contractor that the vehicles are driven regularly at normal speeds to allow the filters to become hot enough so that they clear themselves.

11.5 Vehicle Checks

It is recommended that MPS develop a rigorous vehicle inspection programme that includes key checks prior to any use, either training or operations.

MPS should include the following specific confirmation checks into their vehicle inspections:

- Engine stop tamper seals have not been breached. If they have been breached, pressures could be adversely affected.
- Tamper markings on the minimum angle adjustments on each water jet monitor have not been tampered with. This could mean that the minimum contact distances have decreased and therefore pressures could be increased.
- It is recommended that filling occurs through the external vehicle inlet only, to avoid contamination of the water supply network (see Inspection VIJ).
- Confirm that there is no condensation or potential leaking in the waterproof housing on each of the water jet monitor cameras and that the camera visibility is clear. If not this will involve intervention to dry the housings.

11.6 Further Work for MPS

The testing has highlighted various areas that the MPS are advised to investigate further, including:

- Sound levels taken during the testing indicate that MPS should undertake their own assessments to ensure that they are operating the water cannon within the Control of Noise at Work regulations (Test I, J, P and W). There is an advisory warning that hearing protection may be required for the driver and commander seat positions (Test P). Also the sound levels whilst working at the rear of the donor vehicle on a vehicle-to-vehicle fill need to be assessed to determine if any hearing protection is required (Test S)
- No sound measurements were taken by CAST when the vehicle was being driven at speed, as the vehicles currently have restrictions in place over their usage. If the vehicles are able to be driven on UK highways, it is recommended that this is tested to see the sound effects of the driving engine at operational speeds (Test P).
- Further testing should be explored regarding the temperature in the cab at a variety of environmental conditions (Test Q), including when the vehicle is being driven as speed, as above.
- CAST have not tested the ability to recover (towing) of the vehicles. It is recommended that MPS ensure this is tested.
- It is recommended that MPS produce a recovery strategy for mechanical failure of the vehicles in an operational scenario, including recovery by another water cannon vehicle (depending upon the towing capability) and recovery if only one vehicle was being deployed.
- There has been no testing of the effect of the water jets on street furniture or debris. It is recommended that MPS include this in their training so that the crews can understand any effects more fully.
- As CAST were unable to test the water tank temperature due to the external temperatures at the time of testing, it is advised that MPS ensure that the water tank heater works effectively when the external temperature is below 4°C (Test O).

- Whilst there is internal lighting inside the vehicle, MPS should further investigate the operational usage at night, including confirming that vehicle controls are appropriately illuminated (Test R).

11.7 Other Recommendations

- A level of PPE should be provided to the crews in case the vehicle becomes vulnerable; the MPS should assess what level is required.
- CAST recommends brief re-testing of the PSNI Somati baseline vehicle to verify the stability of the pressure measurement system. It is also recommended that steps are taken (by brief testing or other means) to confirm that the LHS monitor of the PSNI Somati baseline vehicle is appropriately representative of those that have been used in service.
- There is no indirect spray mode on the WaWe9 vehicles. The Germans emulate an indirect mode using a developed tactic which the MPS could also consider.

12. Acknowledgements

CAST would like to thank MPS Public Order colleagues at MPSTC and the MPS's vehicle maintenance contractors for their invaluable support during the trials.

13. Appendix A – Changes to Test Protocol v1.0 to v2.0

During the trials, it became necessary to make some minor changes to the test protocol in light of practical issues that arose. These are reflected in v2.0 of the Test Protocol and the main changes are summarised below:

- Change to Targets – the planned targets proved to be too light and it was not possible to distinguish when if they were being knocked over by the water jet themselves or the surrounding spray. More sturdy versions were created using public order shields attached to public order barriers and weighted down with concrete blocks and tyres.
- Static Target Test – the planned layout of the test was altered slightly due to constrictions in the area of the site used.
- Static Target Test – the furthest distance tested was increased from <redacted> as it was considered to be a more realistic operational range.. Side facing tests were only conducted <redacted> for each vehicle as this was considered to be a realistic operational range (passing of junctions etc)
- Moving Target Test – The test was redesigned after discussion with the cannoneers <redacted>. In addition, the initial method developed for determining accuracy was found to be ineffective due to a large amount of spray providing no clear video footage
- Maximum Distance Test – with the planned targets being too light, this assessment was carried out by the Trials Manager dressed in personal protective equipment, pushing a cage weighted with concrete blocks with a public order shield attached to the front of it, into the water jet on maximum pressure. When the trials manager could feel the force of the jet on the shield, the cage was stopped and the distance then measured.
- Pressure Areas Measured – some of the areas on the pressure measurement system were changed to allow more centralised readings around the peak pressures measured (2x2 cells and 4x4 cells were changed to measure 3x3 cells and 5x5 cells instead).
- Hydrant Fill Test – <redacted>. One vehicle was also tested at 16 bar. This was done as we had extensive data from the daily checks. The 16 bar test was conducted to ensure a different effect was not seen at maximum output.
- Field of View of Cameras Test – driver's reversing camera and blind spot cameras were added to this test. This was done to provide additional information to the MPS.
- Rear Intercom Test – the volunteer outside the vehicle wore a public order helmet with the visor down for each of the tests. This was done to enable the test to be as realistic as possible and under advisement from the MPS staff assisting.
- Vehicle to Vehicle Fill Test – the test vehicle had half a tank of water only. The pressure rig was sited at <redacted>. This was done as we had extensive data from the daily checks
- Water Jets Crossing Test – re-written to make the test procedure clearer.

Appendix B <redacted>

14. Appendix C – <redacted>

15. Appendix D – Water Cannon Test Rig and Pressure Measurement System

The measurements of pressure and force were conducted using a pressure mat system that is mounted on the Water Cannon Test Rig, as illustrated in Figure 6.

The pressure mat was mounted with the centre of the mat at a height of 1.78m from the ground. The mat was attached to a polycarbonate plate, which was securely fixed to a 400mm diameter force plate. This was mounted on a framework with a 1000l water tank for ballast. The framework is supported on 4 high friction machine feet to help resist movement; the wheels are retracted when the rig is in position.

The framework has been designed with a high degree of rigidity to ensure that movement of the frame during testing is eliminated as far as reasonably practicable.

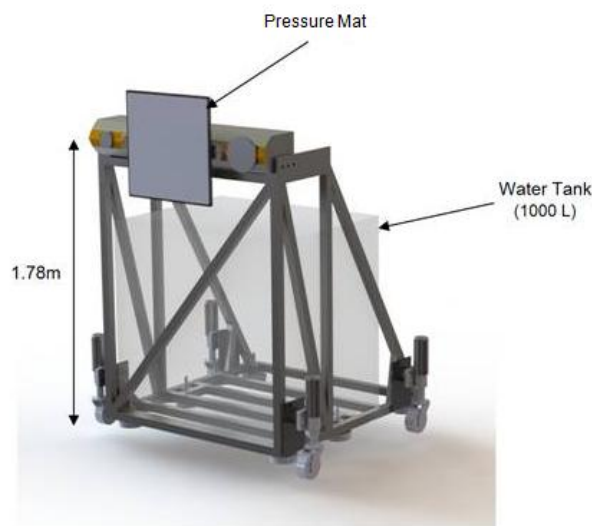


Figure 6 - Water Cannon Test Rig with Pressure Mat Mounting

The pressure mat has the following specification:-

- Supplier - <redacted>
- Software – <redacted>
- Model – HX200:16.16.01 High Speed Sensor
- Active Area 20" x 20" (50.8cm x 50.8cm)
- Resolution 1.25" (3.175cm)
- Sensor array 16 x 16 = 256 individual sensing elements
- Custom calibration 1-80psi. (0.1 – 5.5bar)
- Sampling rate 480Hz (min)

16. Appendix E - Summary of Comparative Pressure Tests

Table 16 Mean Frame Pressure (kPa)

Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

Distance/m		<redacted>			<redacted>			<redacted>		
		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Minimum	Whole Mat	30.7	22.3	25.9	21.0	30.8	35.6	35.4	24.7	39.4
	3x3	55.8	31.7	41.2	22.6	43.9	76.7	64.0	40.4	81.9
	5x5	45.2	27.9	34.5	22.3	36.1	55.5	47.2	35.1	58.9
	7x7	38.7	26.2	30.7	22.2	32.3	45.5	39.6	31.4	48.5
<redacted>	Whole Mat	13.9	14.3	16.4	12.9	22.2	20.7	24.5	16.9	24.3
	3x3	15.7	14.2	22.6	10.9	32.4	28.1	35.3	22.7	38.2
	5x5	15.5	14.3	20.3	12.1	28.5	24.7	31.2	21.2	33.8
	7x7	15.1	14.1	18.5	12.1	25.5	23.6	27.6	19.6	29.8

Distance/m		PSNI		
		LHS	RHS (LHS)	BOTH
Minimum	Whole Mat	49.1	49.1	26.1
	3x3	140.7	140.7	50.1
	5x5	77.6	77.6	44.2
	7x7	56.1	56.1	38.7
<redacted>	Whole Mat	27.1	27.1	27.6
	3x3	47.8	47.8	51.6
	5x5	39.7	39.7	41.6
	7x7	34.7	34.7	34.5






	WaWe9 more than 4sd below PSNI
	WaWe9 more than 2sd but less than 4sd below PSNI
	WaWe9 within ±2sd of PSNI
	WaWe9 greater than 2sd but less than 4sd above PSNI
	WaWe9 more than 4sd above PSNI

Table 17 Max Frame Pressure (kPa)

Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

Distance/m		<redacted>			<redacted>			<redacted>		
		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Minimum	Whole Mat	70.1	44.0	41.9	36.9	87.3	60.3	63.4	44.7	71.8
	3x3	256.6	92.2	102.6	114.6	164.4	182.0	150.7	125.3	168.8
	5x5	122.2	64.0	73.4	60.6	127.9	106.0	94.2	67.1	114.3
	7x7	88.5	60.6	52.6	50.7	106.8	71.1	82.4	57.9	82.1
<redacted>	Whole Mat	35.8	28.3	39.8	33.5	45.8	40.9	44.0	36.0	44.1
	3x3	67.3	57.2	93.5	182.0	127.4	120.9	117.2	78.3	133.6
	5x5	50.9	45.2	54.4	43.0	82.7	80.2	73.0	53.5	84.3
	7x7	55.1	36.8	42.9	36.0	63.5	58.6	67.0	43.1	58.8

Distance/m		PSNI		
		LHS	RHS (LHS)	BOTH
Minimum	Whole Mat	131.2	131.2	74.3
	3x3	435.5	435.5	372.9
	5x5	204.4	204.4	190.5
	7x7	156.6	156.6	158.7
<redacted>	Whole Mat	114.8	114.8	67.0
	3x3	297.4	297.4	186.8
	5x5	182.7	182.7	123.5
	7x7	140.5	140.5	89.8






	WaWe9 more than 50% below PSNI
	WaWe9 more than 25% but less than 50% below PSNI
	WaWe9 within ±25% of PSNI
	WaWe9 greater than 25% but less than 50% above PSNI
	WaWe9 more than 50% above PSNI

Table 18 Mean Frame Contact Area (cm²)

Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

Distance/m		<redacted>			<redacted>			<redacted>		
		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Mimumum	Whole Mat	479.4	440.5	646.4	564.7	231.1	674.8	388.7	625.9	438.4
	3x3	86.2	83.7	85.3	68.0	82.2	89.7	86.7	83.4	89.4
	5x5	196.7	187.0	219.2	163.4	164.2	236.6	212.1	213.6	208.0
	7x7	313.1	267.7	357.1	269.6	208.1	390.0	314.0	344.9	309.6
<redacted>	Whole Mat	365.2	321.9	602.9	336.9	499.5	921.3	602.0	491.7	682.3
	3x3	57.3	58.8	78.1	47.4	83.0	83.4	82.1	78.5	89.6
	5x5	133.9	126.6	190.3	112.2	199.4	218.2	213.9	184.9	233.9
	7x7	212.7	195.8	301.2	183.4	310.9	392.4	376.9	284.6	390.6

Distance/m		PSNI		
		LHS	RHS (LHS)	BOTH
Mimumum	Whole Mat	555.8	555.8	394.0
	3x3	78.5	78.5	34.1
	5x5	188.7	188.7	68.7
	7x7	313.8	313.8	111.1
<redacted>	Whole Mat	360.6	360.6	430.7
	3x3	75.3	75.3	87.7
	5x5	154.3	154.3	179.4
	7x7	215.7	215.7	266.8

Table 19 Maximum Frame Contact Area (cm²)

Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

		<redacted>			<redacted>			<redacted>		
Distance/m		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Minimum	Whole Mat	852.8	731.9	969.8	883.1	407.3	943.6	586.7	887.1	647.2
<redacted>	Whole Mat	774.2	590.7	1308.5	733.9	788.3	1318.6	891.1	830.6	953.6

		PSNI		
Distance/m		LHS	RHS (LHS)	BOTH
Minimum	Whole Mat	544.4	544.4	885.1
<redacted>	Whole Mat	594.8	594.8	653.2

Table 20 Mean Frame Estimated Load (N)

Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

Distance/m		<redacted>			<redacted>			<redacted>		
		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Minimum	Whole Mat	1442.6	969.0	1657.2	1177.0	701.9	2388.2	1360.7	1532.9	1706.0
	3x3	489.9	266.9	354.8	183.9	359.1	689.0	560.9	343.0	730.9
	5x5	905.2	524.1	758.2	411.6	584.7	1311.6	994.9	751.4	1215.0
	7x7	1209.2	698.1	1094.4	659.1	662.6	1767.8	1229.4	1076.7	1487.4
<redacted>	Whole Mat	520.5	468.3	973.5	451.1	1104.6	1908.8	1467.0	832.1	1647.4
	3x3	101.2	90.1	183.8	64.6	275.4	245.7	305.6	187.2	343.4
	5x5	224.8	191.9	396.9	157.7	575.4	564.4	690.3	402.0	791.7
	7x7	339.8	289.5	570.8	254.9	799.9	957.9	1047.0	563.3	1162.9

Distance/m		PSNI		
		LHS	RHS (LHS)	BOTH
Minimum	Whole Mat	1554.0	1554.0	1289.3
	3x3	1049.9	1049.9	329.4
	5x5	1320.0	1320.0	515.8
	7x7	1478.0	1478.0	662.7
<redacted>	Whole Mat	956.2	956.2	1164.6
	3x3	380.7	380.7	456.3
	5x5	625.7	625.7	757.9
	7x7	752.3	752.3	922.4











	WaWe9 more than 4sd below PSNI
	WaWe9 more than 2sd but less than 4sd below PSNI
	WaWe9 within ±2sd of PSNI
	WaWe9 greater than 2sd but less than 4sd above PSNI
	WaWe9 more than 4sd above PSNI

Table 21 Maximum Frame Estimated Load (N)

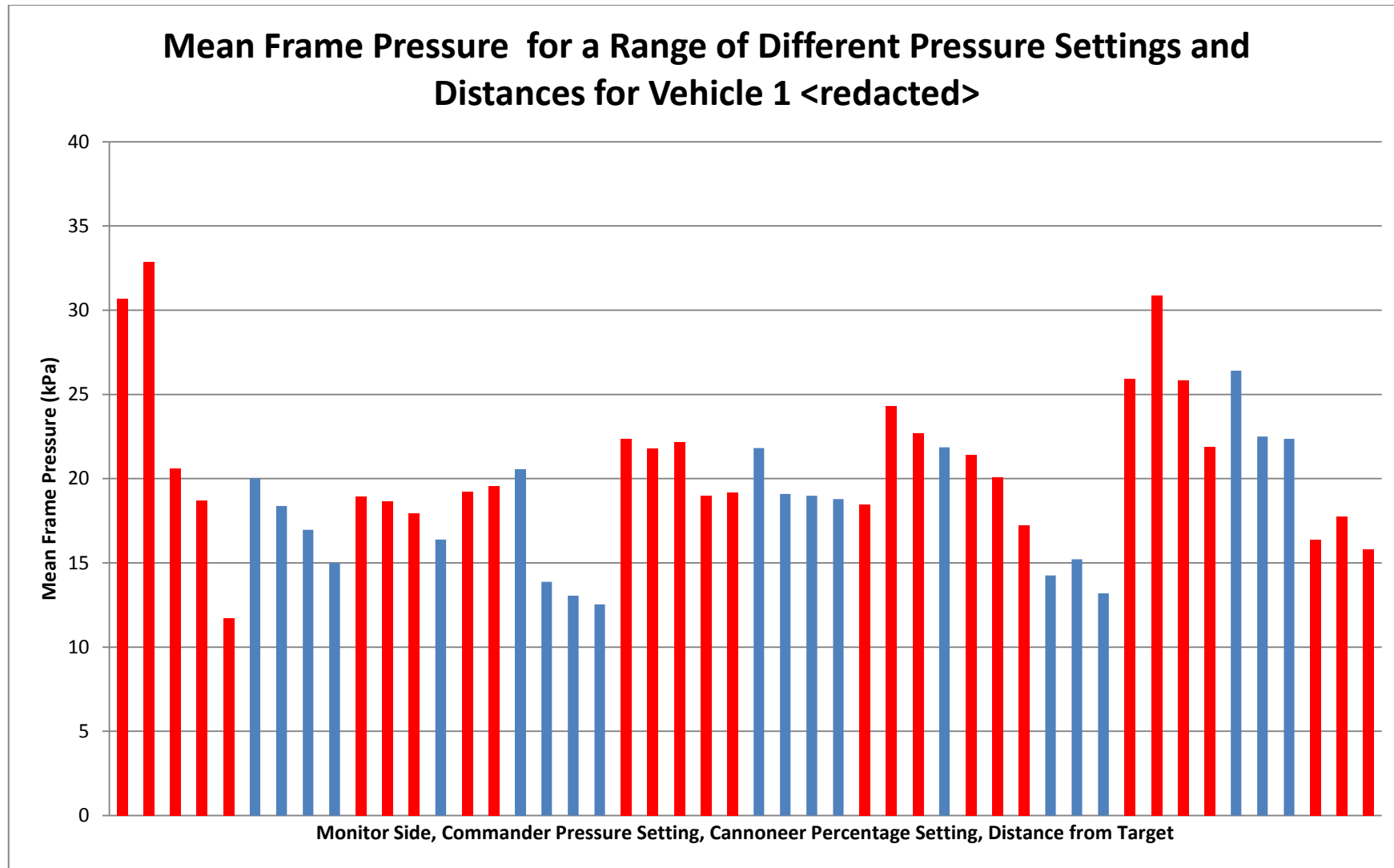
Minimum distance <redacted>; Maximum pressure settings (16 bar and 100%)

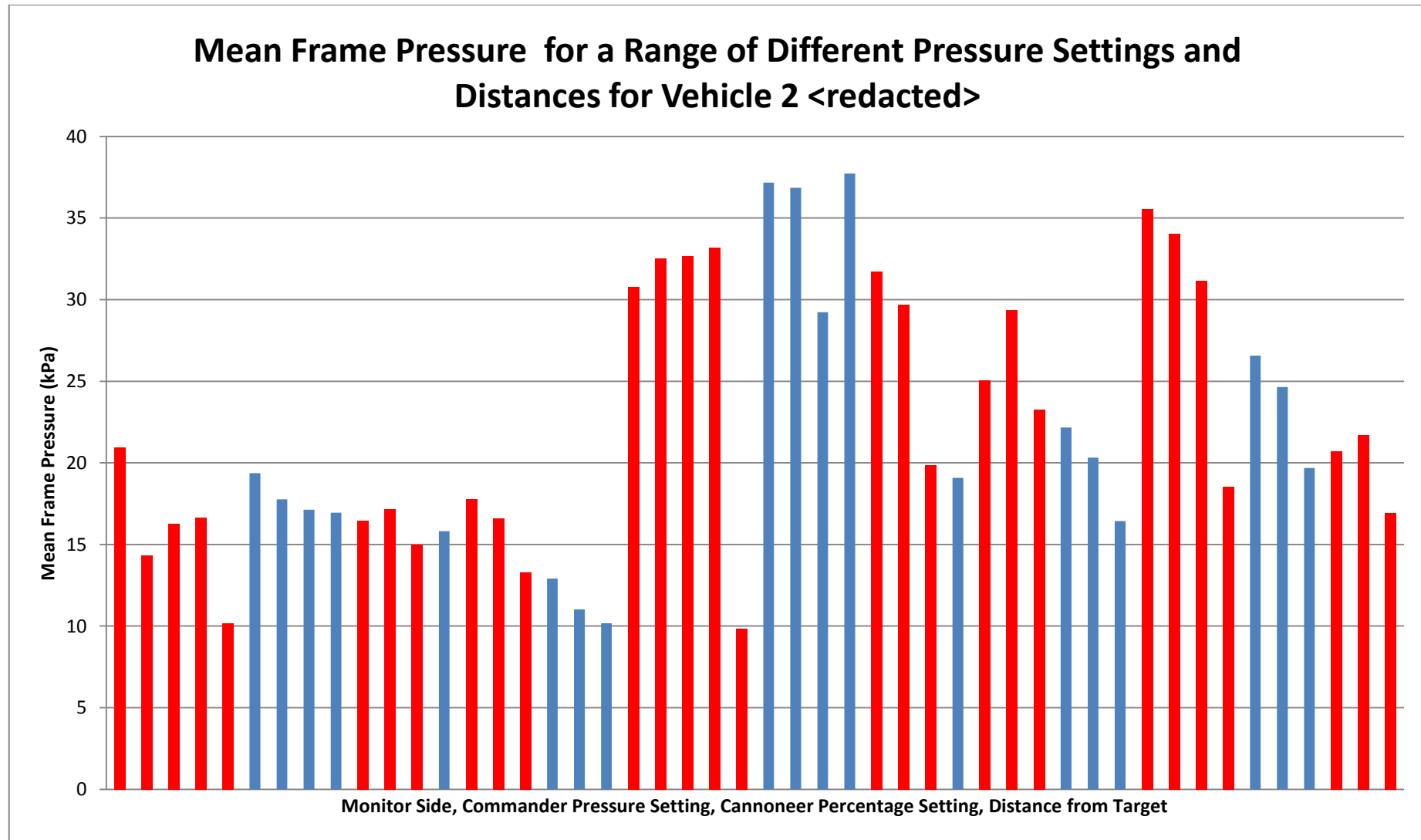
Distance/m		<redacted>			<redacted>			<redacted>		
		LHS	RHS	BOTH	LHS	RHS	BOTH	LHS	RHS	BOTH
Mimimum	Whole Mat	3105.4	1840.1	2442.7	2256.6	1363.4	4034.4	2175.5	2317.0	2719.8
	3x3	2327.7	836.8	931.2	727.1	1009.6	1651.1	1282.3	1136.6	1531.9
	5x5	2673.0	1288.2	1518.5	1123.3	1151.3	2309.5	1717.7	1548.1	2165.7
	7x7	2800.8	1443.3	1875.4	1529.1	1334.7	2884.1	2032.8	1872.6	2547.9
<redacted>	Whole Mat	1382.5	1251.8	2533.3	1381.7	2618.0	3698.5	2695.3	1703.7	2814.7
	3x3	567.2	447.8	848.3	561.0	1156.3	1097.2	1063.4	710.1	1212.6
	5x5	898.6	774.9	1345.1	712.4	1584.3	1934.6	1672.2	1182.7	2124.3
	7x7	1070.2	915.9	1675.6	958.2	1806.7	2684.7	2030.7	1427.2	2609.6

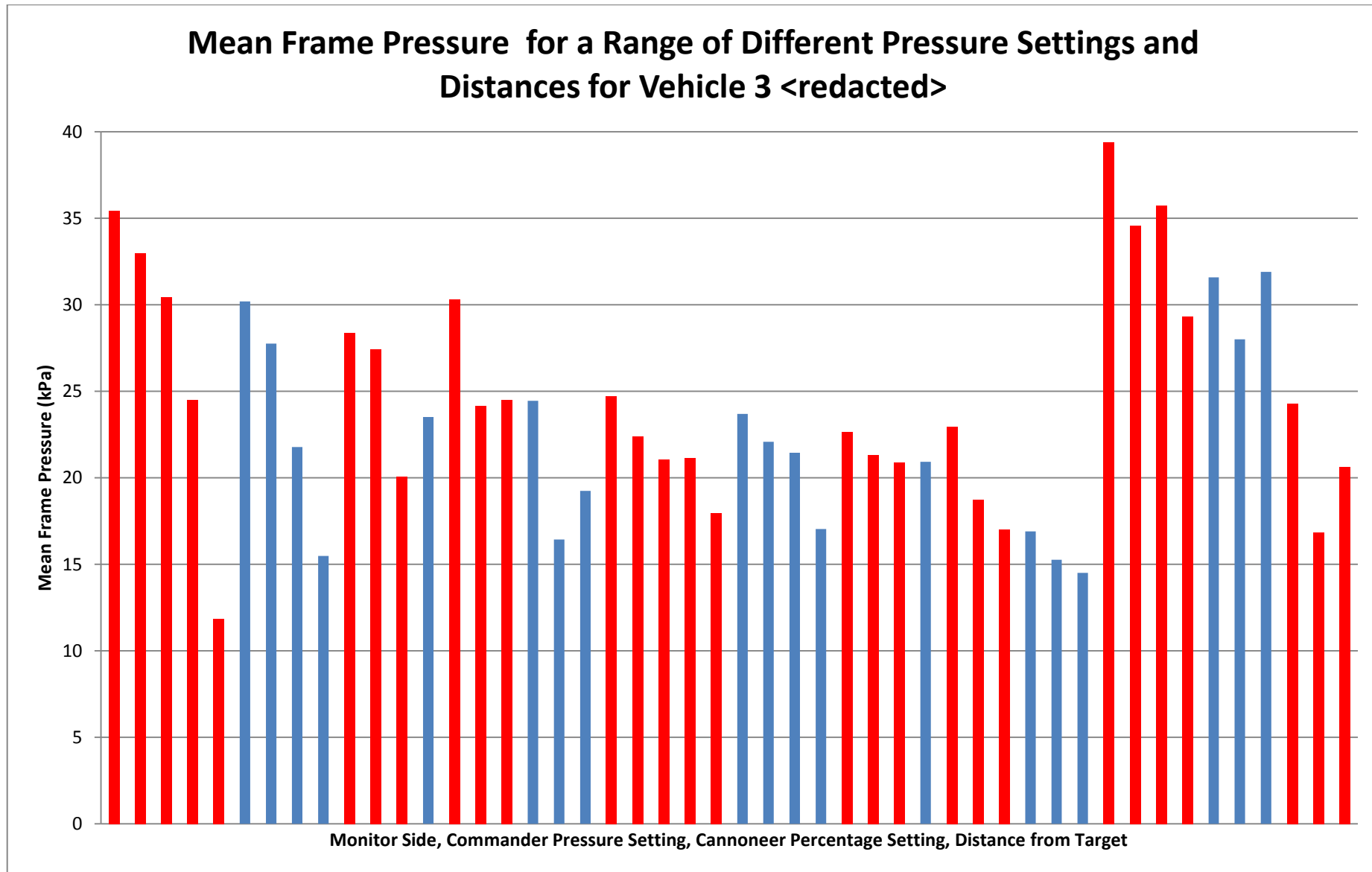
Distance/m		PSNI		
		LHS	RHS (LHS)	BOTH
Mimimum	Whole Mat	3304.2	3304.2	3753.5
	3x3	2839.8	2839.8	2505.3
	5x5	3121.2	3121.2	2741.6
	7x7	3264.4	3264.4	2891.2
<redacted>	Whole Mat	2999.2	2999.2	2464.5
	3x3	2697.9	2697.9	1694.5
	5x5	2879.8	2879.8	2093.8
	7x7	2945.7	2945.7	2257.0

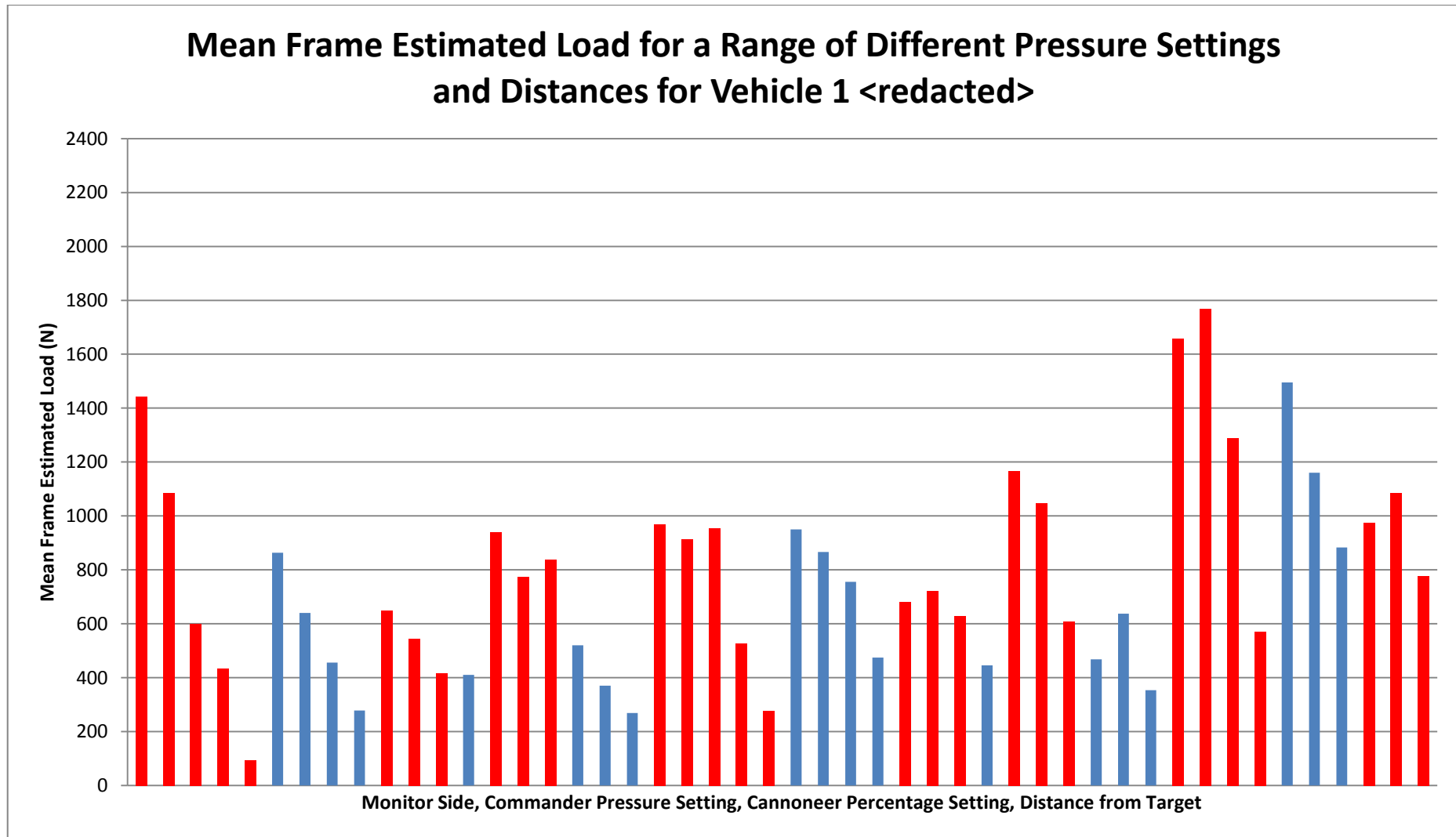
	WaWe9 more than 50% below PSNI
	WaWe9 more than 25% but less than 50% below PSNI
	WaWe9 within ±25% of PSNI
	WaWe9 greater than 25% but less than 50% above PSNI
	WaWe9 more than 50% above PSNI

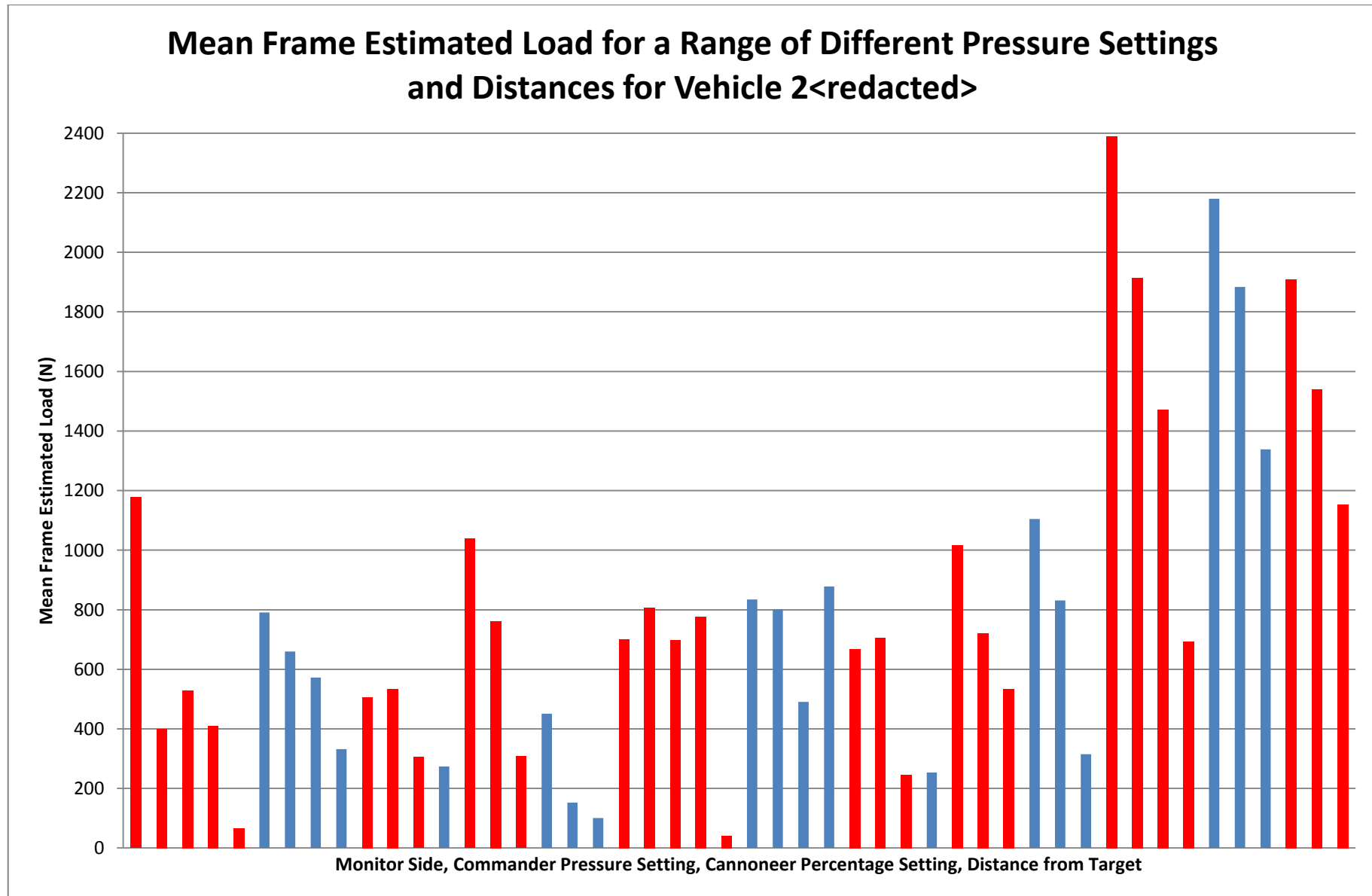
17. Appendix F – Summary of Further Pressure Tests Conducted

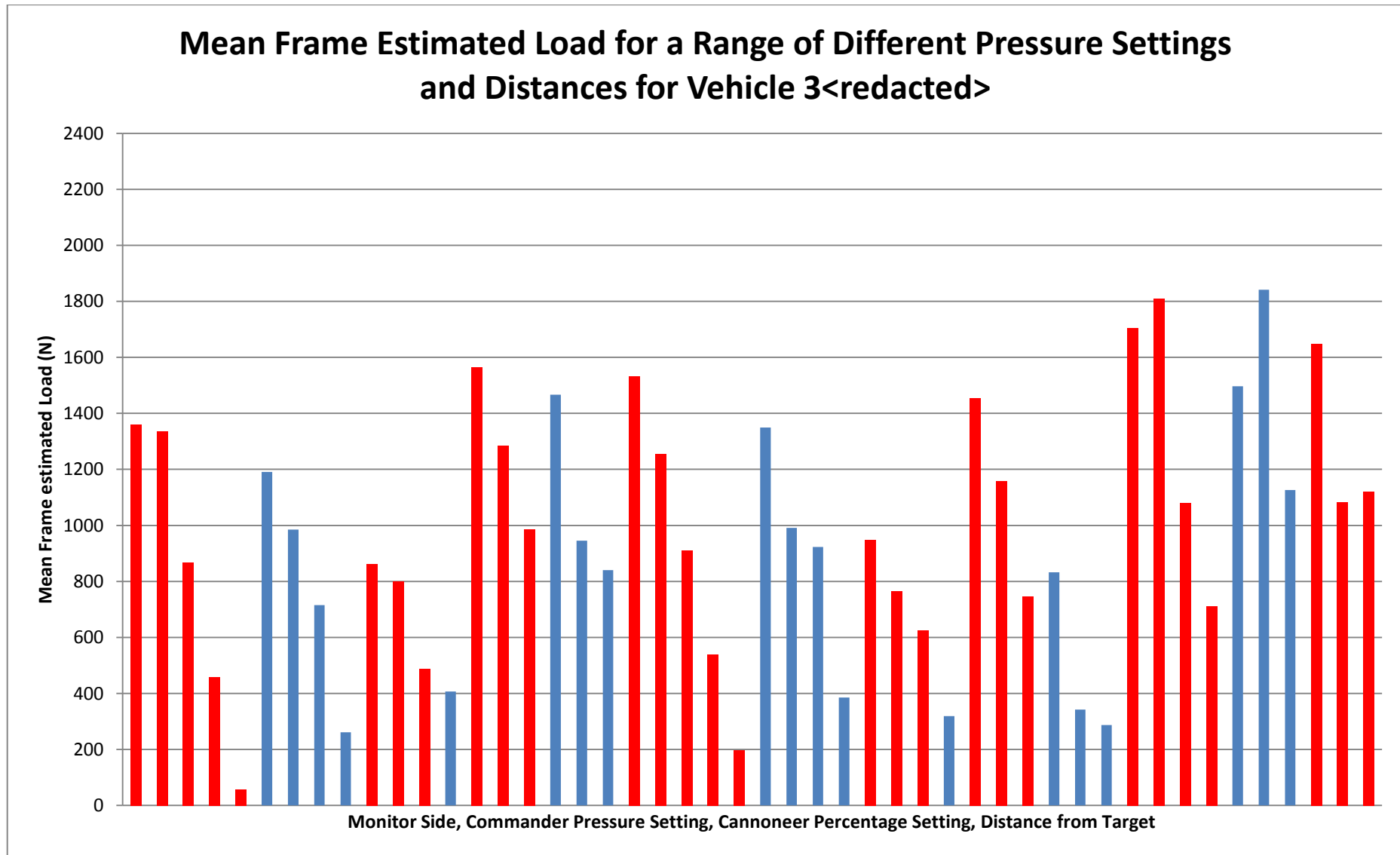


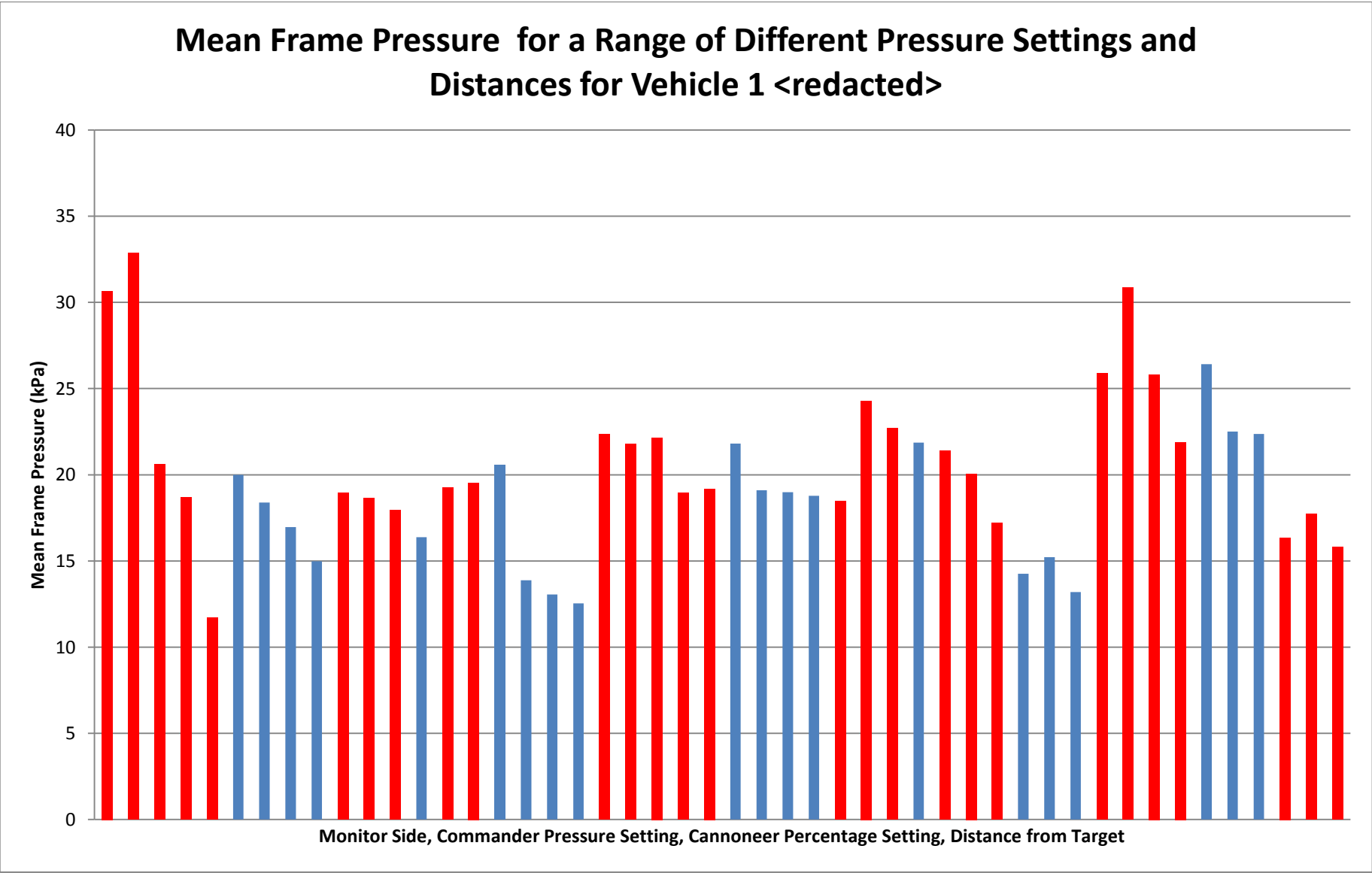


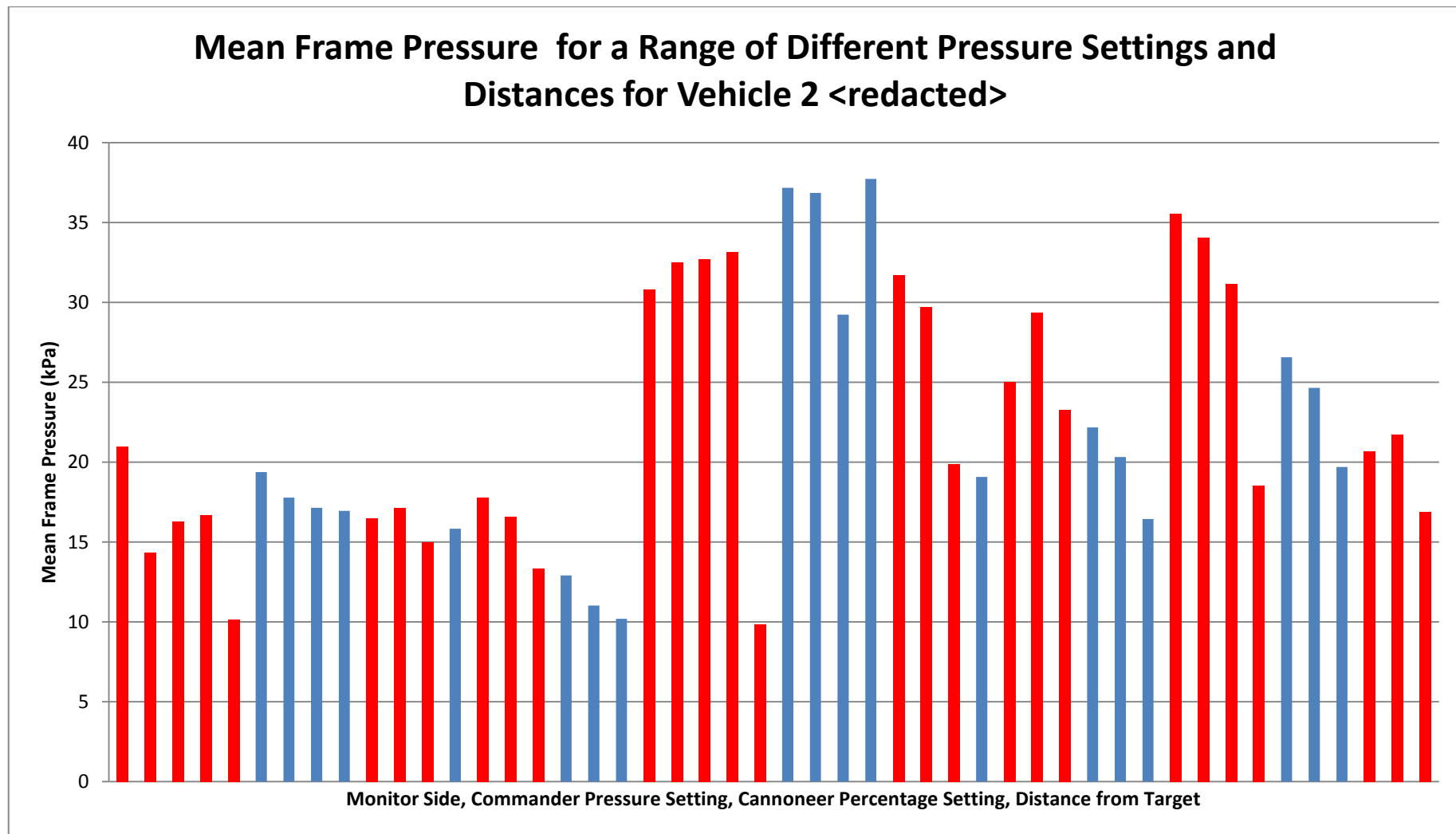


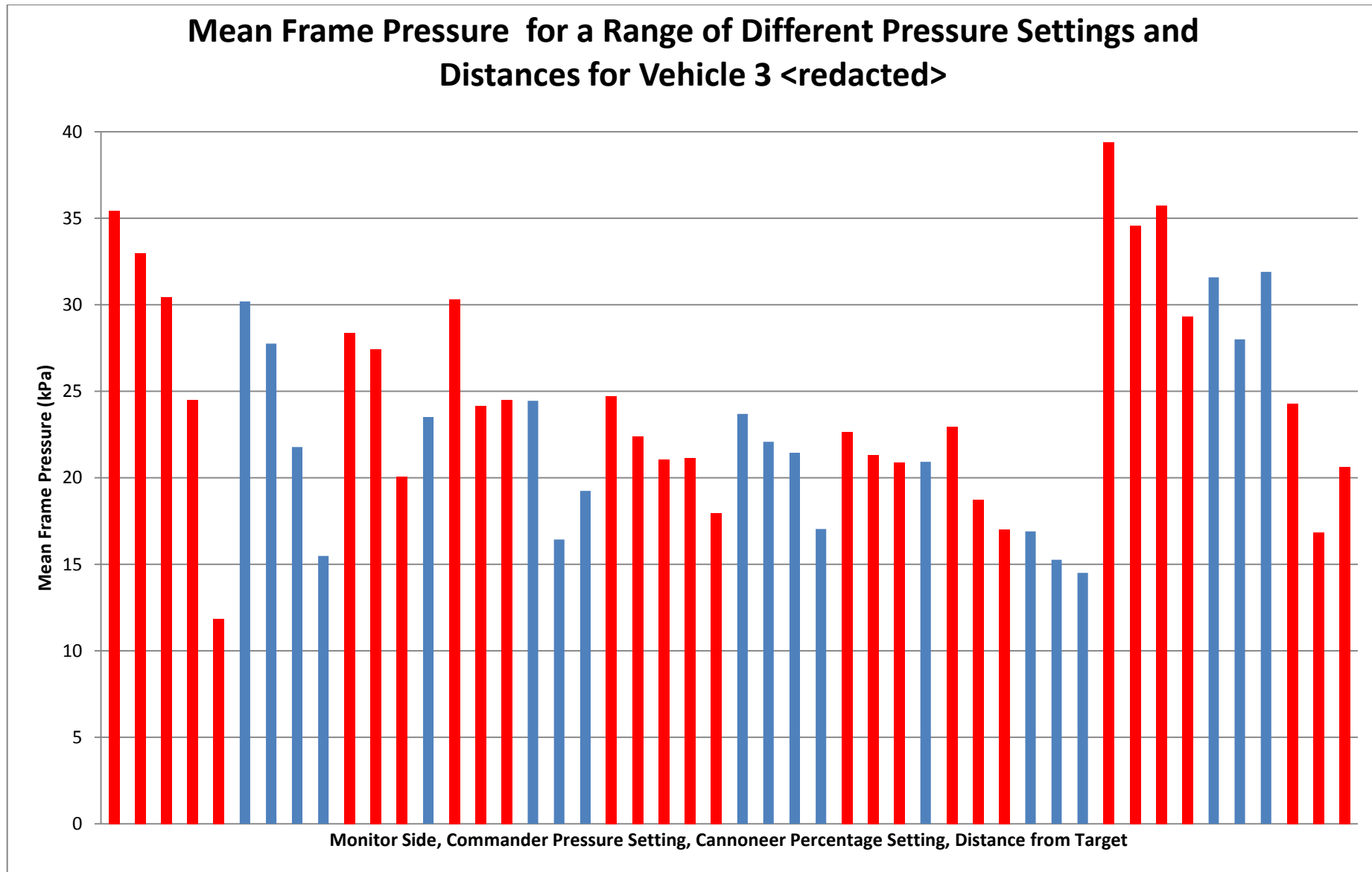


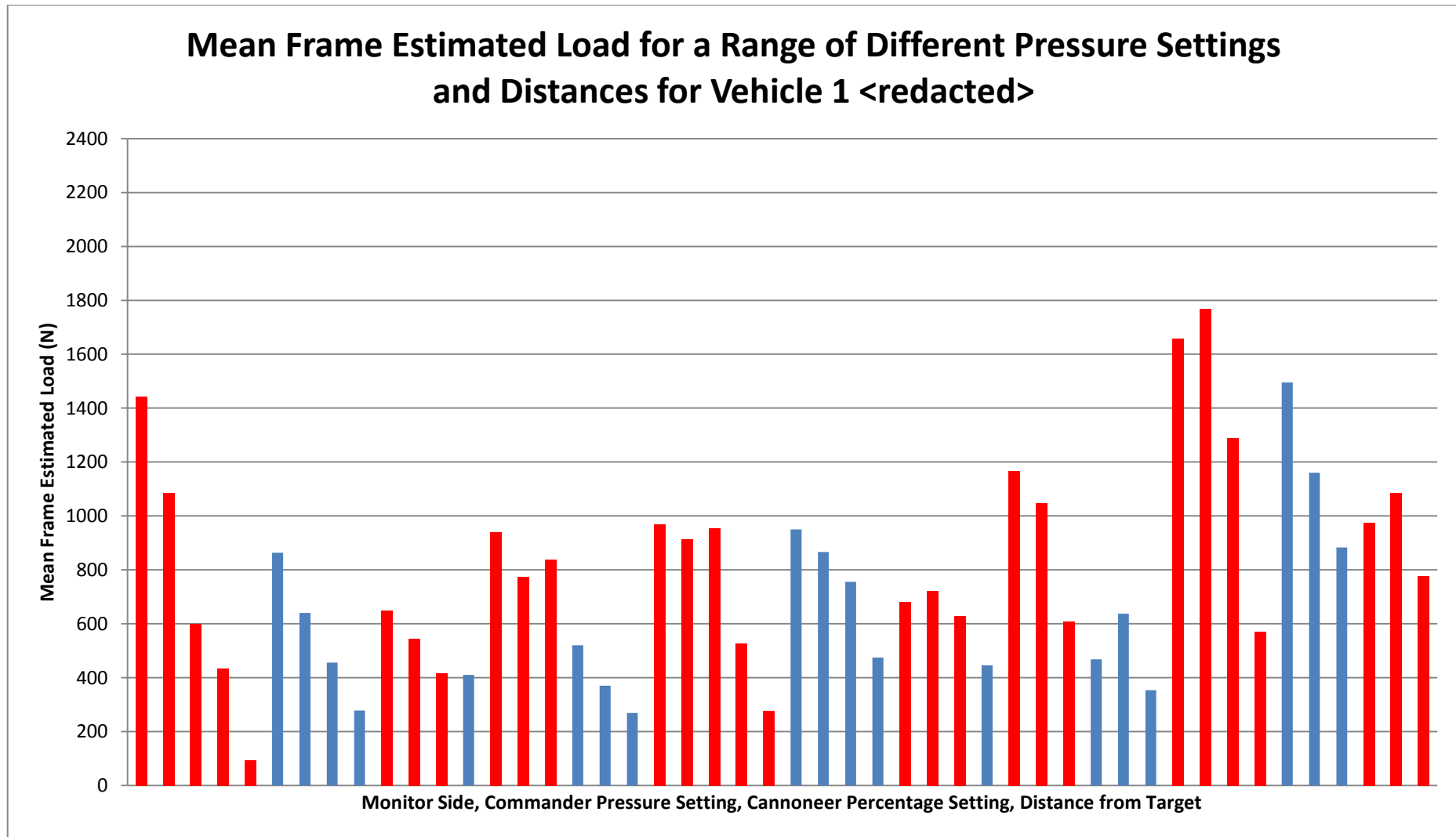


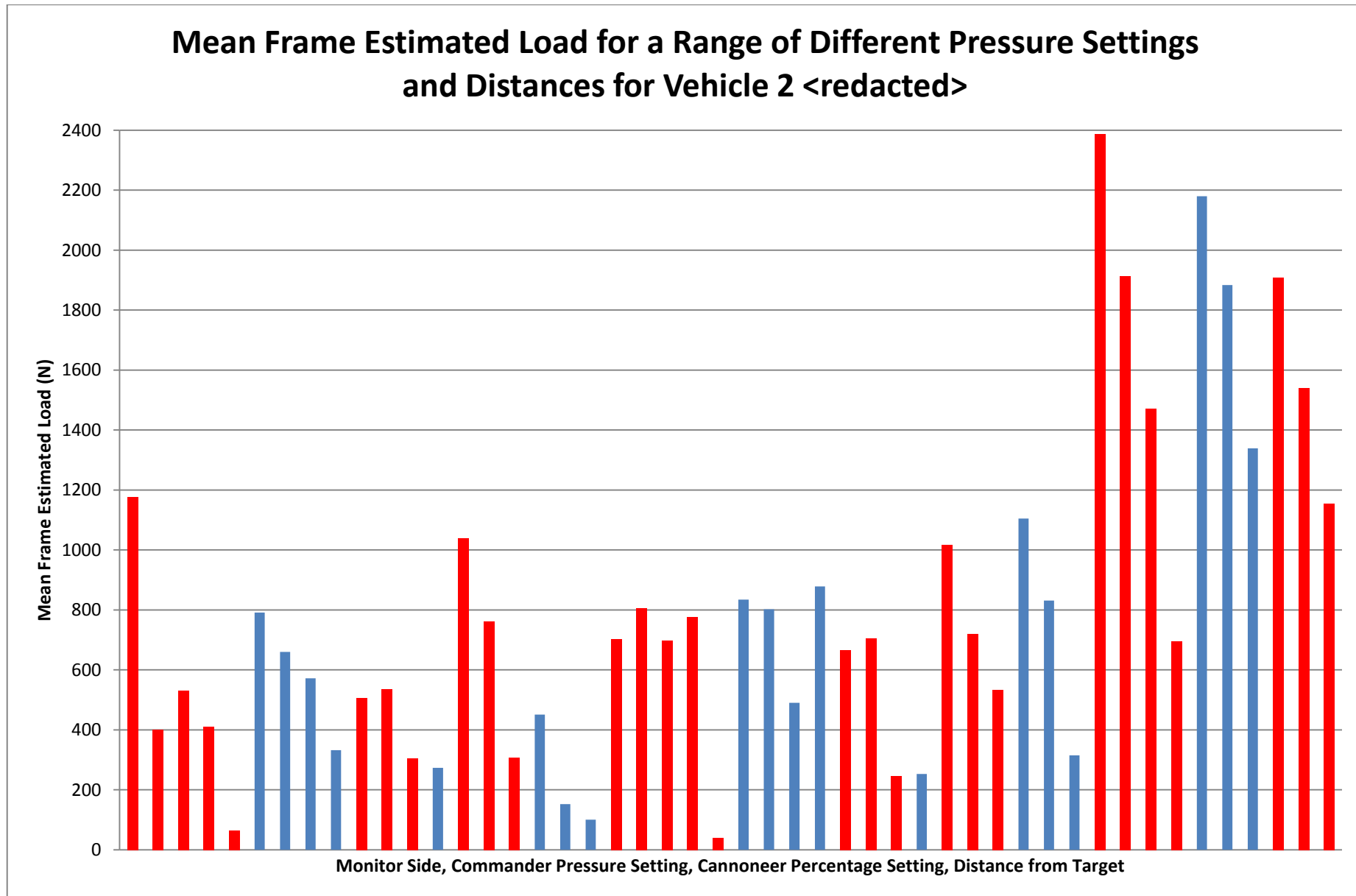


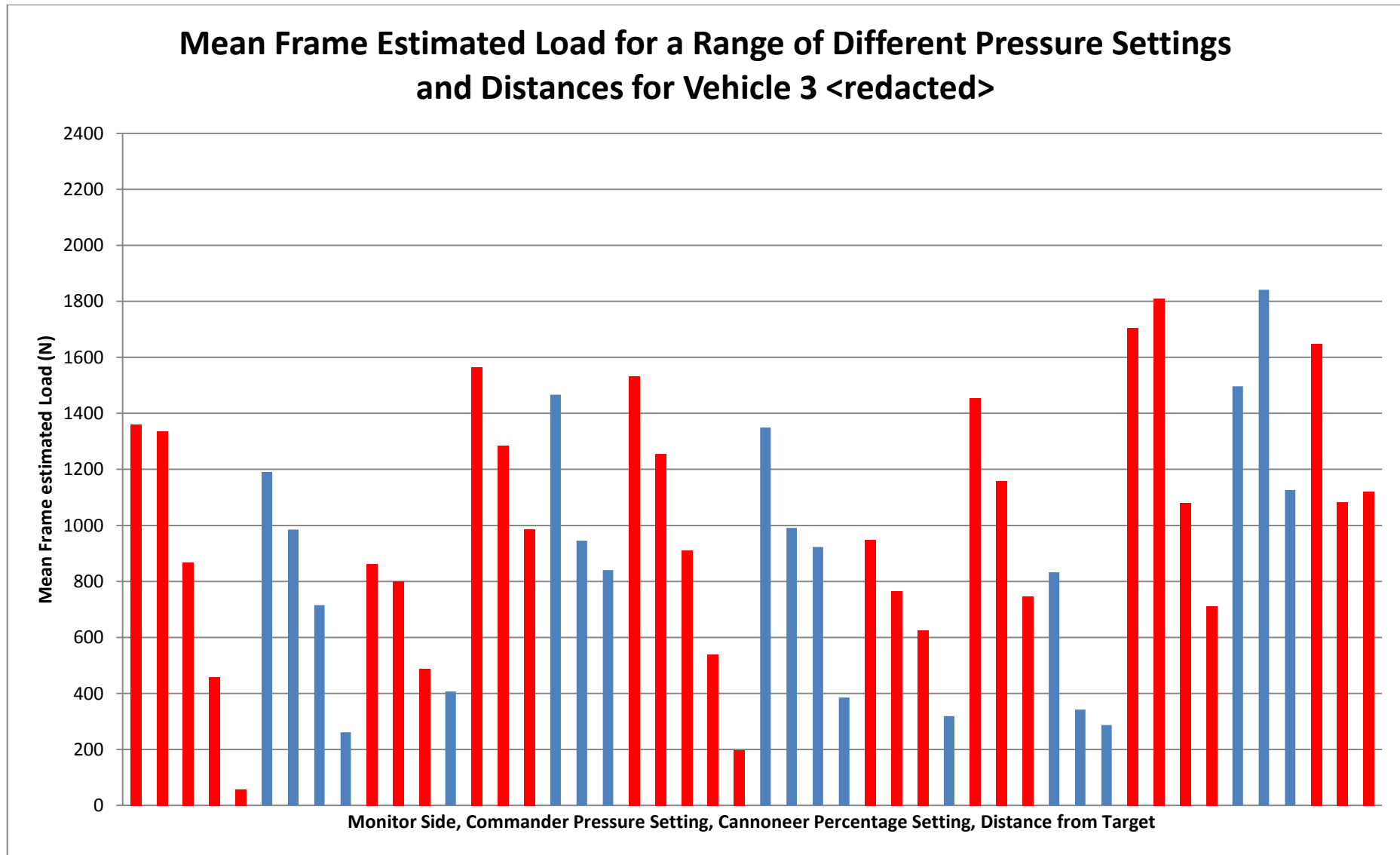












18. Appendix G – Glossary of Terms and Abbreviations

CAST	Centre for Applied Science and Technology
CoP	College of Policing
Dstl	Defence science and technology laboratory
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
kPa	Kilopascal – Unit of measure of pressure
LEZ	London Emission Zone
LHS	Left Hand Side of the vehicle when considered from the driver's seat
MPS	Metropolitan Police Service
MPSTC	Metropolitan Police Specialist Training Centre
N	Newton – measurement of force applied
PPC	Protective Personnel Carrier, also known as Public Order Carrier – Vehicle used to transport public order officers
PSNI	Police Service of Northern Ireland
RAG	Red, Amber, Green Status
RASTI	Rapid Speech Transmission Index
RHS	Right Hand Side of the vehicle when considered from the driver's seat
s, ms, μ s	Second, millisecond, microsecond
SACMILL	Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons
sd	Standard deviation
SoP	Standard Operating Procedure
STI	Speech Transmission Index
TETRA	Terrestrial Trunked Radio (police radio system)
WaWe9	Ziegler WasserWerfer 9000 (vehicle mounted water cannon)

Cannoneer	Police officer trained to operate a water jet monitor
Commander (crew commander)	A police officer trained to direct the crew of a water cannon. Has overall control of the maximum water pressure allowed to a water jet monitor
Contact area	Section of the pressure mat, within any individual frame, that is contacted by the water jet with a pressure greater than 5.52 kPa
Element	A single cell on the pressure mat (the mat has 256 elements)
Frame	One complete scan of the pressure mat
Frame load	Total force associated with a single frame i.e. frame pressure x contact area
Frame pressure	The pressure applied to the mat for one frame and is the average of all the elements that are within the contact area
Loggist	Police officer trained to take a written record regarding decisions taken in the water cannon by the crew commander, cannoneers or driver
Lux	Measure of light level
Maximum frame contact area	Maximum contact area that is observed over a 20 s period based on a 5 point (10 ms) moving average
Maximum frame estimated load	Highest value of frame load (force) observed during the 20 s period based on a 5 point (10 ms) moving average
Maximum frame estimated load 3x3, 5x5, 7x7	Highest value of frame load (force) observed during the 20 s period, based on a 5 point (10 ms) moving average for areas equating to 3x3, 5x5 or 7x7 elements
Maximum frame pressure	Highest value of pressure observed during the 20 s period based on a 5 point (10 ms) moving average
Maximum pressure 3x3, 5x5, 7x7	The highest value of pressure observed during the 20 s period, based on a 5 point moving average, for areas equating to 3x3, 5x5 or 7x7 elements. These maximum zones can be identified by visual inspection of the pressure maps, or semi-automatically by the measurement system software which tracks the peak element

Mean frame contact area	Average contact area that is observed over a 20 s period (calculated from individual frame contact areas)
Mean frame estimated load	Average frame load (force) measured over a 20 s period
Mean frame pressure	Average pressure that is applied over a 20 s period (calculated from the frame pressures)
Pressure Mat	A 50.8 x 50.8 cm pressure sensitive mat used for the recording of contact pressures, areas and forces. Consisting of 256 individual elements in a 16 x 16 array.
Somati	Somati RCV 9000 (vehicle mounted water cannon)
Specification 13	Automotive and Equipment Section (AES) Automotive EMC Assessment and Installation Evaluation Specification 13, A specification relating to the electromagnetic compatibility (EMC) assessment and installation evaluation of electrical, electronic and radio equipment in Police & Fire Service vehicles”
Video monitor	View screen showing images from cameras
Water cannon	The vehicle in its entirety
Water Jet	The jet of water emitted from the water jet monitor
Water Jet Monitor (also referred to as a Monitor)	The device which is used to spray water from the vehicle and control the direction of the water