Test Protocol for X26 Tasers:

Discussion document for CEW Workshop 2010

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with input from many others

[1]Carleton University, [2]MPB Technologies

Outline

- Summary / Outline
- Goal
- Test Outline
  - Test Protocol
  - Test System
  - Data analysis
  - Reports
- Summary / Next Steps

- Initial comments:
  - Approach may not perfect, but we can't wait.
  - Why is this a set of slides, not a document?

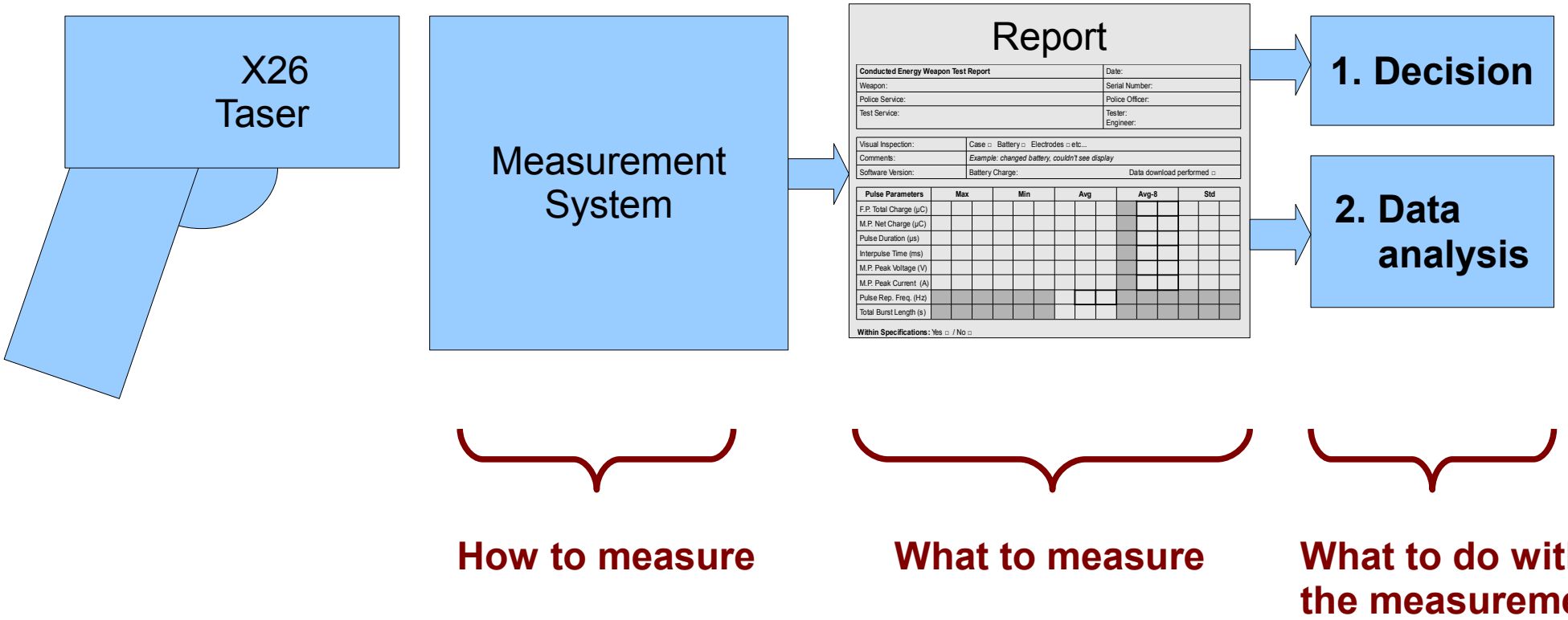
Summary / Overview

1. What to measure?

2. How to measure?

3. What to do with the measurements?

Summary / Overview



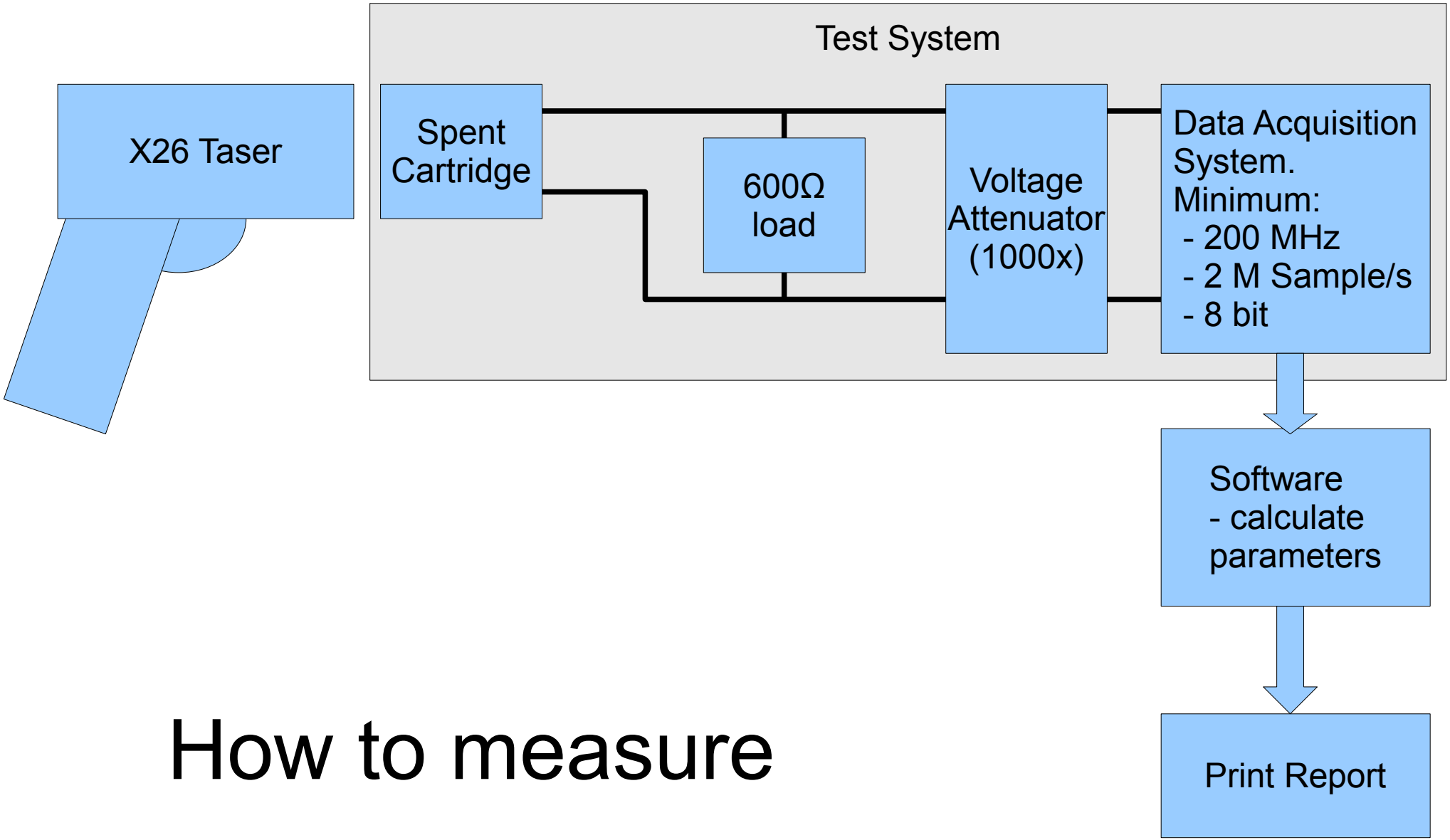
What to measure

Conducted Energy Weapon Test Report	Date:
Weapon:	Serial Number:
Police Service:	Police Officer:
Test Service:	Tester: Engineer:

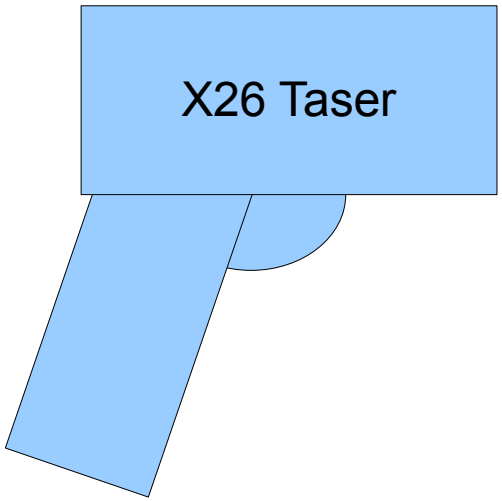
Visual Inspection:	Case □ Battery □ Electrodes □ etc...	
Comments:	*Example: changed battery, couldn't see displa*	
Software Version:	Battery Charge:	Data download performed □

Pulse Parameters	**Max**			**Min**			**Avg**			**Avg-8**			**Std**		
F.P. Total Charge (µC)															
M.P. Net Charge (µC)															
Pulse Duration (µs)															
Interpulse Time (ms)															
M.P. Peak Voltage (V)															
M.P. Peak Current (A)															
Pulse Rep. Freq. (Hz)															
Total Burst Length (s)															

Within Specifications: Yes □ / No □



How to measure



Measurement System

Print Report

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Total Burst Length (s)															

Within Specifications: Yes □ / No □

What to do with measures

1. Decision

In spec. / out of spec.
(*Use* / Don't *Use*)

2. Data storage

Enable analysis for:
- Weapon lifecycle
- Predict malfunction
- Problem serial number
- Post-incident

Goal

Test protocol serves two functions

- Is weapon within specification (use/don't use)?
- Generate Weapons Characterization data

Is weapon in spec?

Decision: *Use* / Don't *use*

Based on two tests:

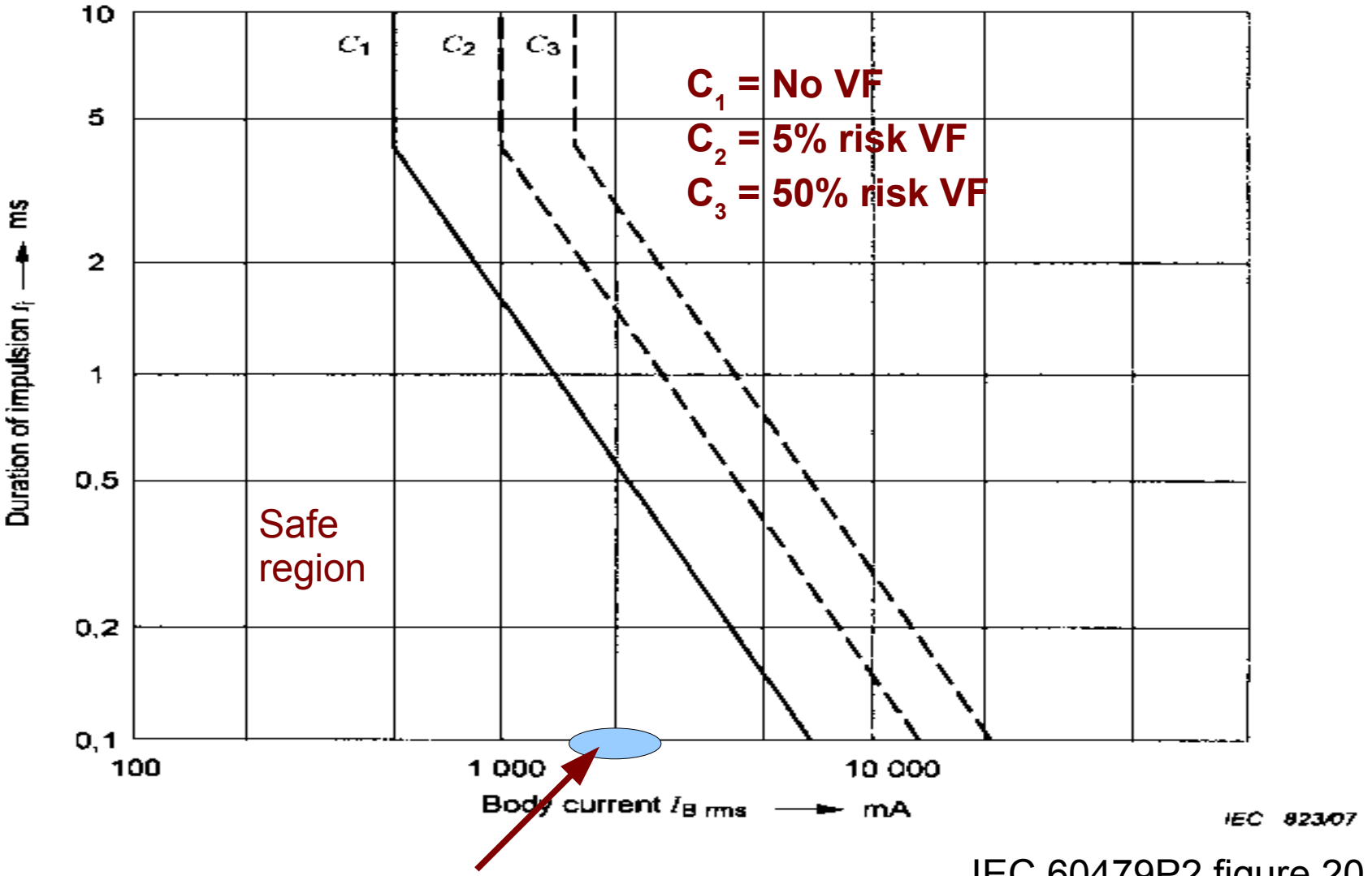
1. Test to document from Taser International [1]
2. Test to additional specifications based on operational and safety data

[1] TASER X26TM Series Electronic Control Device Specifications (Law Enforcement X26). Version 2.0. February 6, 2009:, from "Test Concepts X26 v6"

Is weapon in spec?

- Spec from Taser International [1]
  - Fire once before testing
  - Tests against the average of the last 8 pulses of 5 parameters.
- Spec from operational/safety data
  - Tests will change as we learn more
  - *Comment:* It is important to ensure we collect the right parameters now to enable these decisions

IEC Safety standards



IEC 60479P2 figure 20

X26 Taser is approximately here
- analysis by P Savard (2008) and by DP Dawson *etal* (2010)

How to interpret IEC 60479

Suggests Taser Int. limits more stringent than IEC.

However,

- IEC uses on total absolute charge, not net charge
- IEC uses on maximum pulse, not average
- IEC suggests you should scale for body mass
  - Anecdotal evidence: taser less effective on large subjects
- IEC threshold is much (up to10x) lower for some cases (Heart arrythmia events)
- Ventricular fibrillation (VF) isn't the only concern
- IEC is based on old (50's and 70's) data

How to manage this uncertainty?

Future-proofing

- Make sure we record all the parameters which are likely to be relevant to safety tests
- Specifically, max + min (not only not average)
- Parameters for
  - Safety
    - based on electrical safety specs and research
  - Operational
    - indications of poor device functioning device

Characterization Data

Performance data on all weapons tested should be kept in order to facilitate analysis to determine

- Weapon lifecycle
- Prediction of malfunction
- Determine any vulnerable serial number sequences
- Forensic examination (post incident)

Basic Test Outline

A: Test Protocol

- Weapon is 1) inspected, 2) connected to the test system, 3) fired three times for 5s

B: Test System

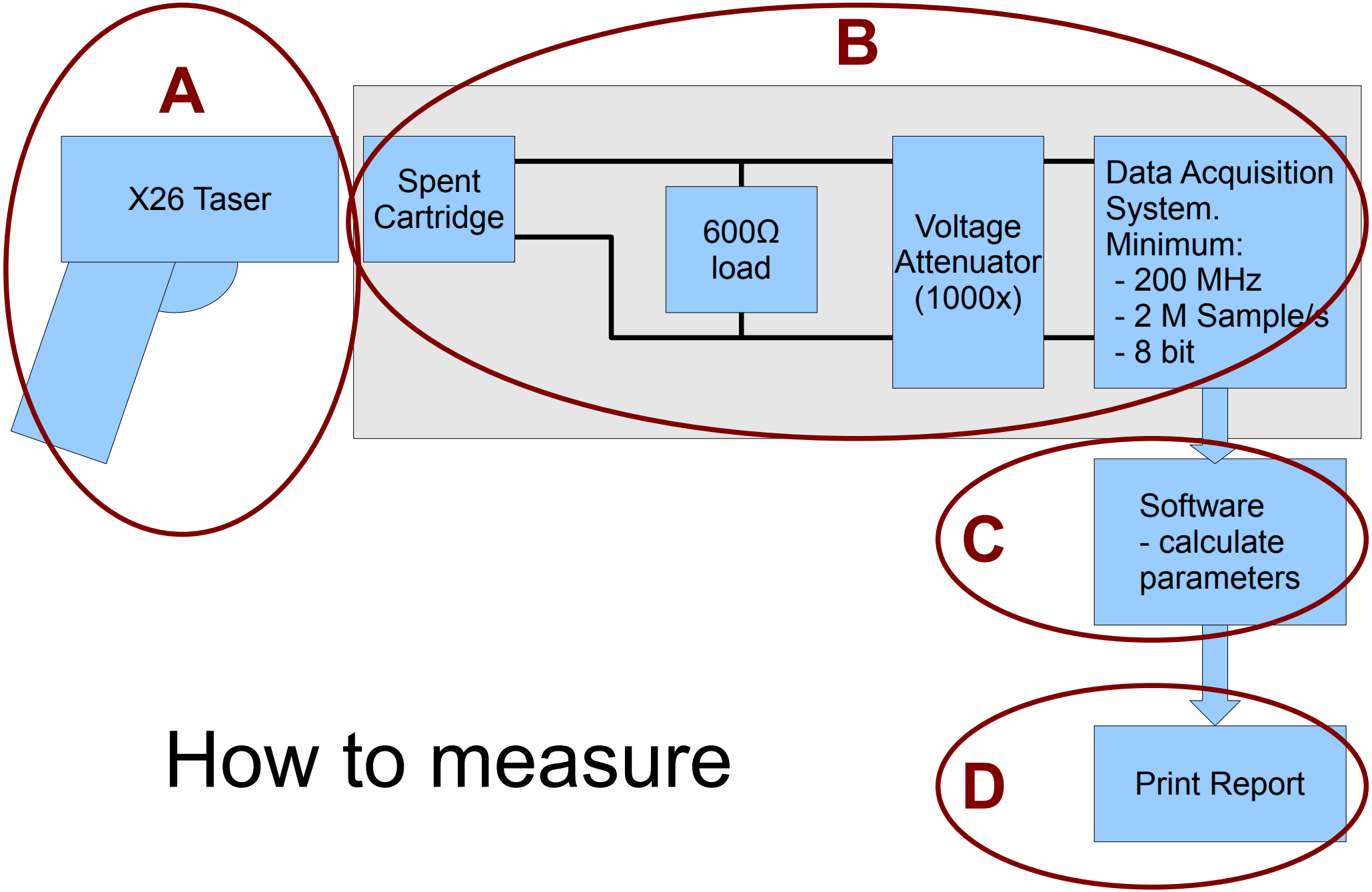
- 1) Weapon connects to spend cartridge, 2) Wires to 600Ω load, 3) Voltage data recorded

C: Data analysis

- 1) Parameters for each pulse calculated, 2) Summary data calculated

D: Reporting

- 1) use/don't use, 2) Report printed and stored



How to measure

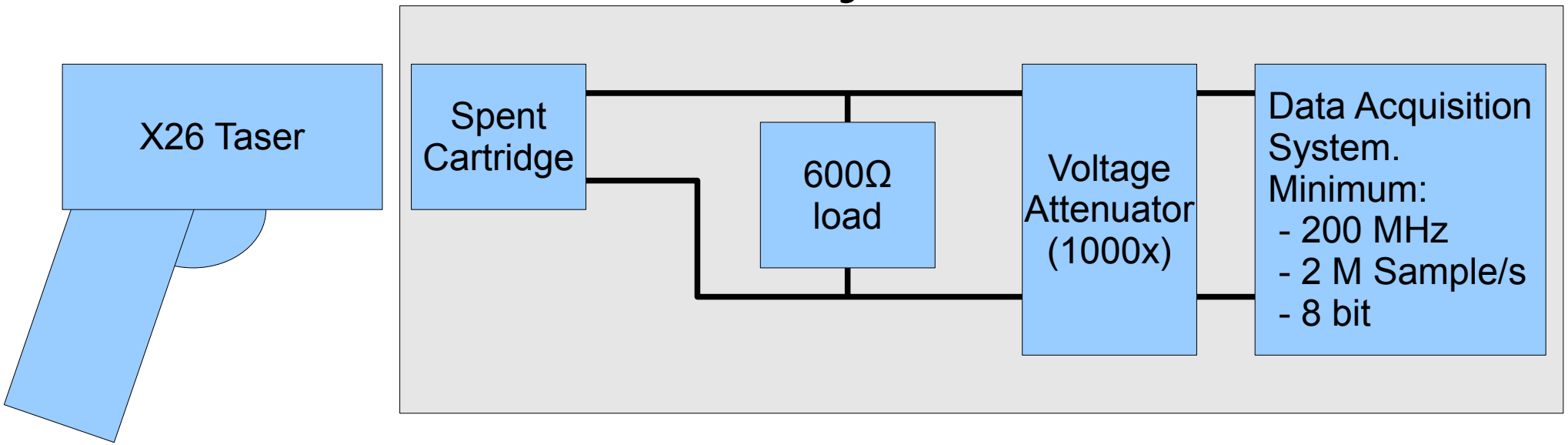
A: Test Protocol

- Weapon Serial / model number recorded.
- Visual inspection of the weapon
- Download and recording of usage data from weapon
- Weapon is connected to test system
- Weapon is fired three times and electrical output recorded
- End of test: Weapon is disconnected

Comments on *Test Protocol*

- Visual inspection looks for physical impairment to testing such as poor fitting of the battery pack or safety and trigger switches.
- No pre-firing of weapon
  - The first firing into the load is thus equivalent to the *pre-fire* in the protocol from Taser International.
  - First firing ***will not be used*** to test against specs from Taser International.
  - First firing data is useful for data analysis to establish trends (ie. may be early indication of performance issues)

B: Test system



- Weapon connects to spent cartridge
- Wires to 600Ω non-inductive load
- Voltage data is recorded

Test system: Spent Cartridge

- Spent Cartridge will stabilize the weapon during firing
- Nominal 1mm air gap between electrodes on weapon and cartridge
- Wires should be of appropriate gauge and voltage rating. Use wiring best practices

Test system: Load

- A 600Ω load was chosen as representative of the electrical resistance of a subject.
- The load should be non-inductive below 1MHz
- The load should be rated for a minimum power dissipation of 10W
- Calibration of the exact resistance of the load is required. Repeated calibrations should be performed as required. Calibration via 4-wire measurement with calibrated ohmmeter

Why 600Ω?

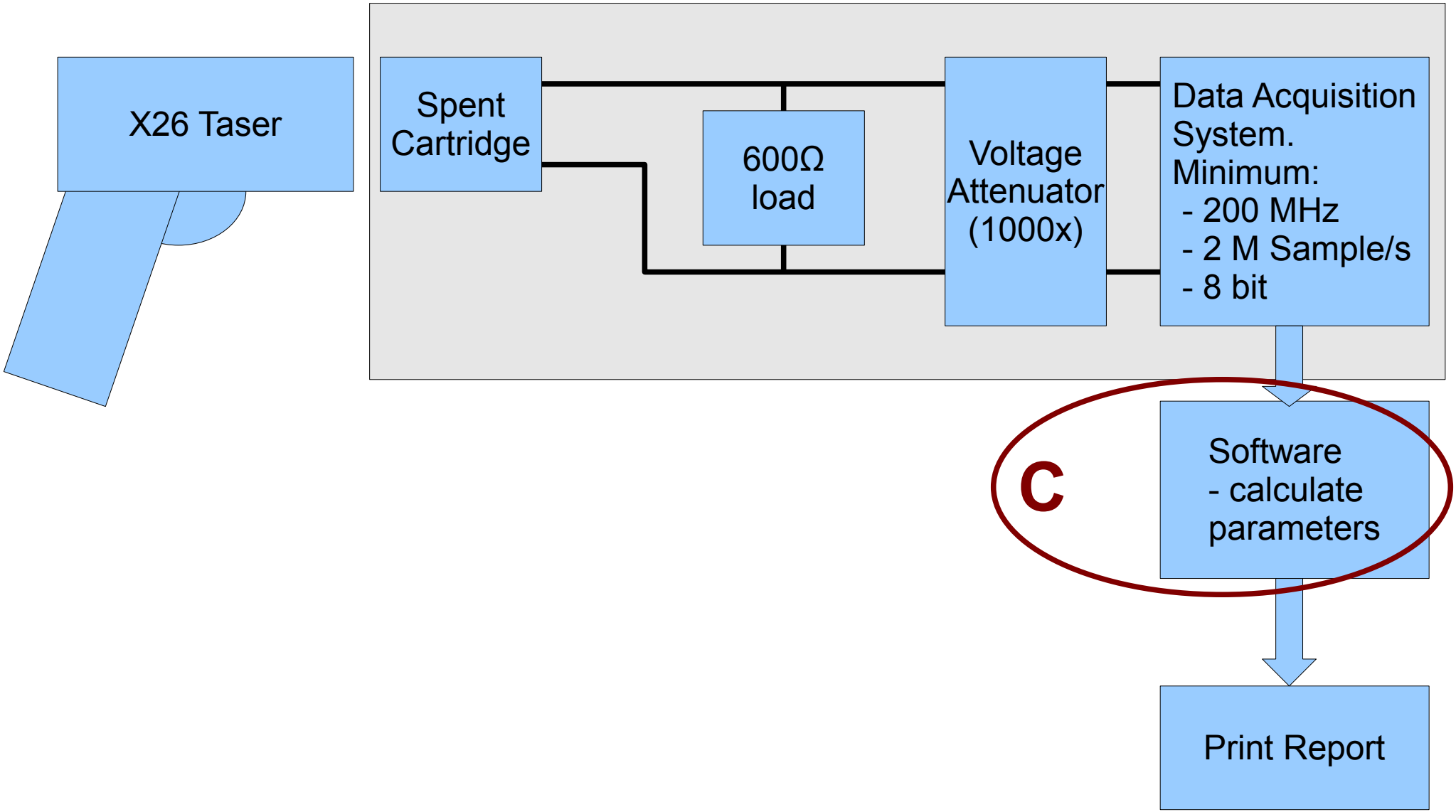
- The value of 600Ω was chosen by Taser Int.
  - At one point (see Ian Sinclair's history) a value of 250Ω was used.
- Clearly, 600Ω should be used for the testing against the Taser specs
- We could specify a different load for other tests.
- However, the choice of 600Ω is reasonable
  - Good average body conductivity estimate
  - Taser charge is relatively independent of load
- We need to explain this choice well

Test system: Data Acquisition

- Normally, a calibrated voltage attenuator is required.
  - *Comment:* Most systems have used a 1000x
- Voltage data from all pulses must be recorded
  - *Comment:* It is acceptable to either: 1) record continuously throughout the pulse time, 2) record each pulse with a minimum pre-trigger of 4μs
  - *Comment:* It is not necessary to independently record current. Current may be derived from the voltage measurements

Test system: Data Acquisition (con't)

- The minimum specifications for the data acquisition system are:
  - Bandwidth: 200 MHz
  - Sample rate: 2 Msample/s
  - Minimum data resolution: 8 bit
  - Minimum voltage resolution: 25 V
  - Signal must not be clipped (voltage out of range). Recorded trace must be tested for clipped values (equal to maximum converter value)


X26 Taser
Spent Cartridge
600Ω load
Voltage Attenuator (1000x)
Data Acquisition System.
Minimum:
- 200 MHz
- 2 M Sample/s
- 8 bit
C
Software
- calculate parameters
Print Report

C: Data Analysis

- Parameters for each pulse calculated,

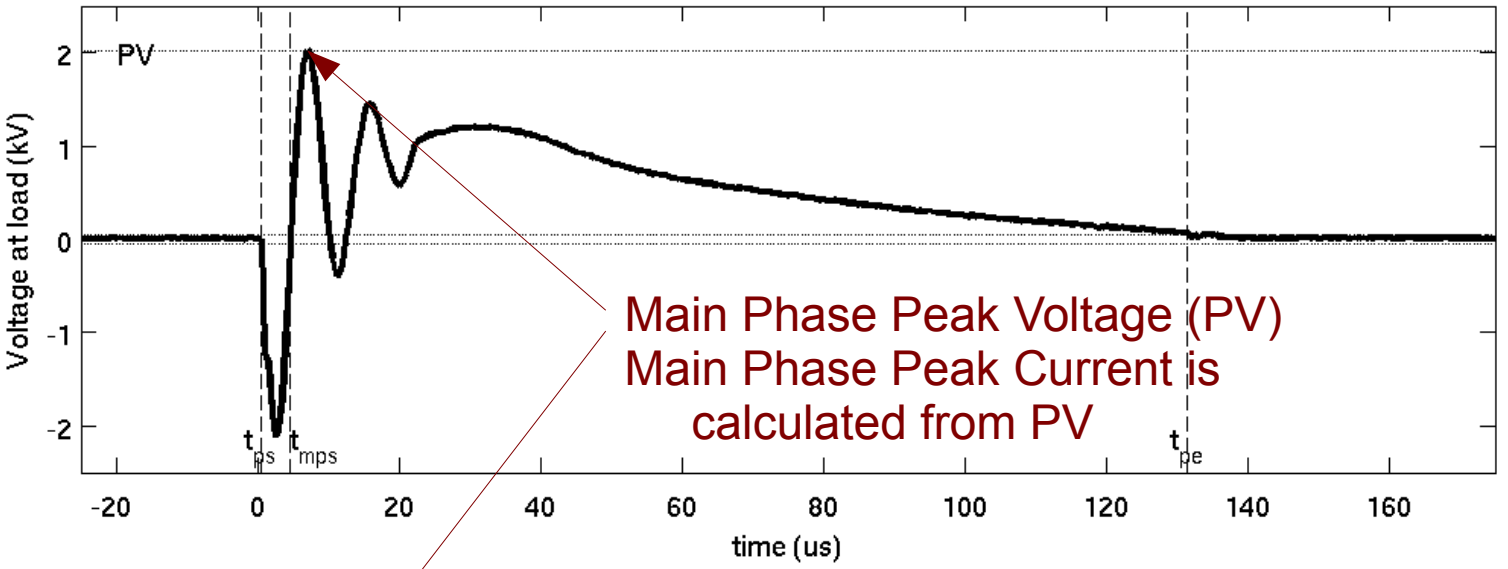
Not in TI spec [1]

  - Main Phase Peak Voltage (V)
  - Main Phase Peak Current (A)
  - Full Pulse Total Charge (μC) ✓
  - Main Phase Net Charge (μC)
  - Pulse Duration (μs)
  - Interpulse Time (ms) ✓

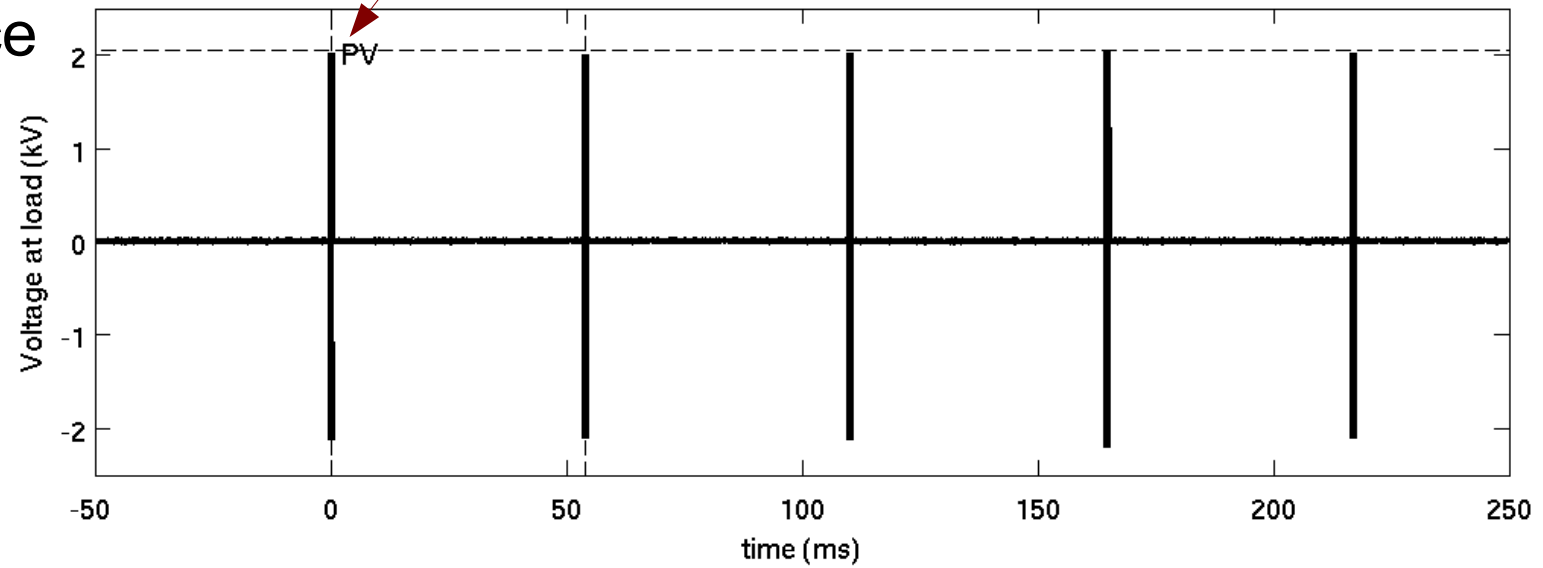
- Summary data calculated
  - Max, min, average, std and avg8 (avg of last 8) calculated
  - Pulse Repetition Freq (PRF)= 1/avg(interpulse time)
  - Total Burst Length = sum(interpulse time) ✓

X26 Taser: Pulse parameters

Single Pulse

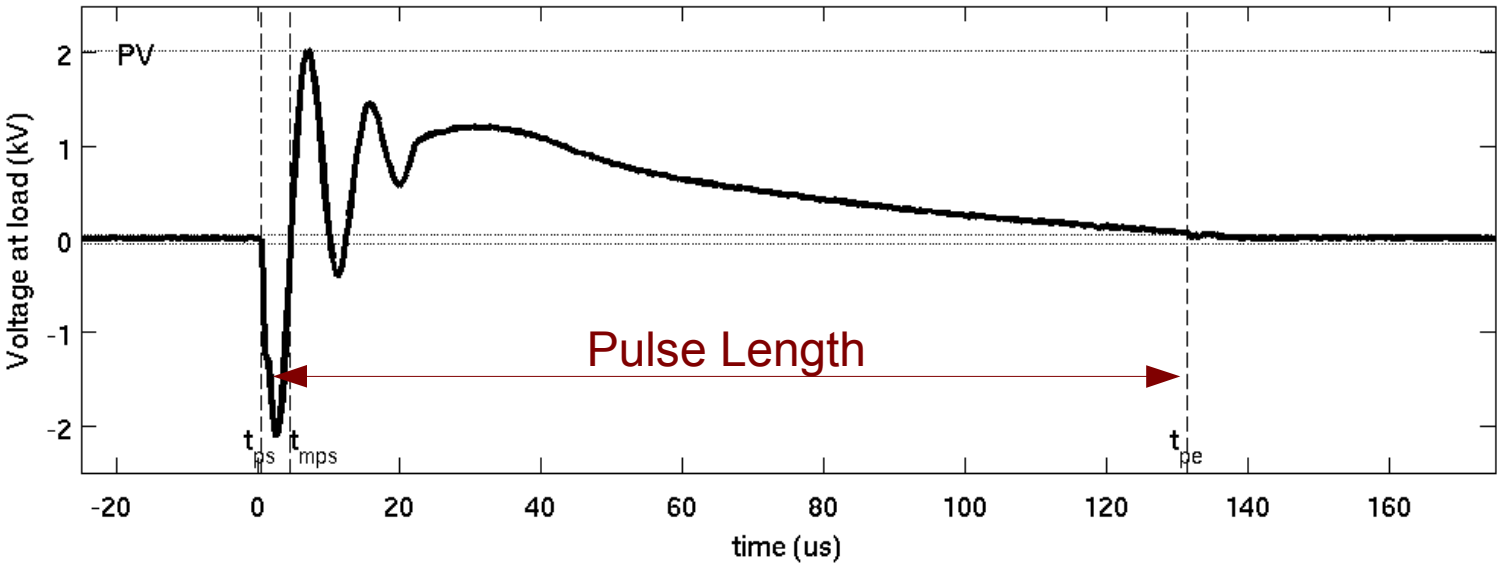


Pulse Sequence

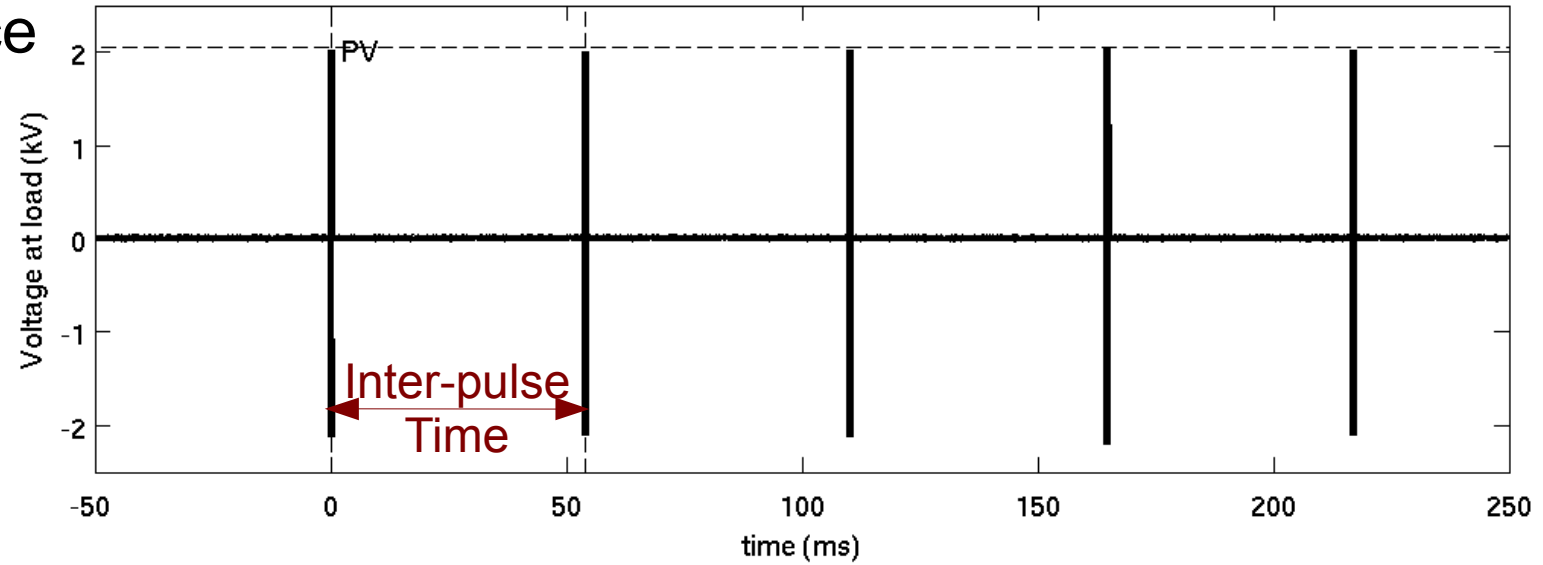


X26 Taser: Pulse parameters

Single Pulse



Pulse Sequence

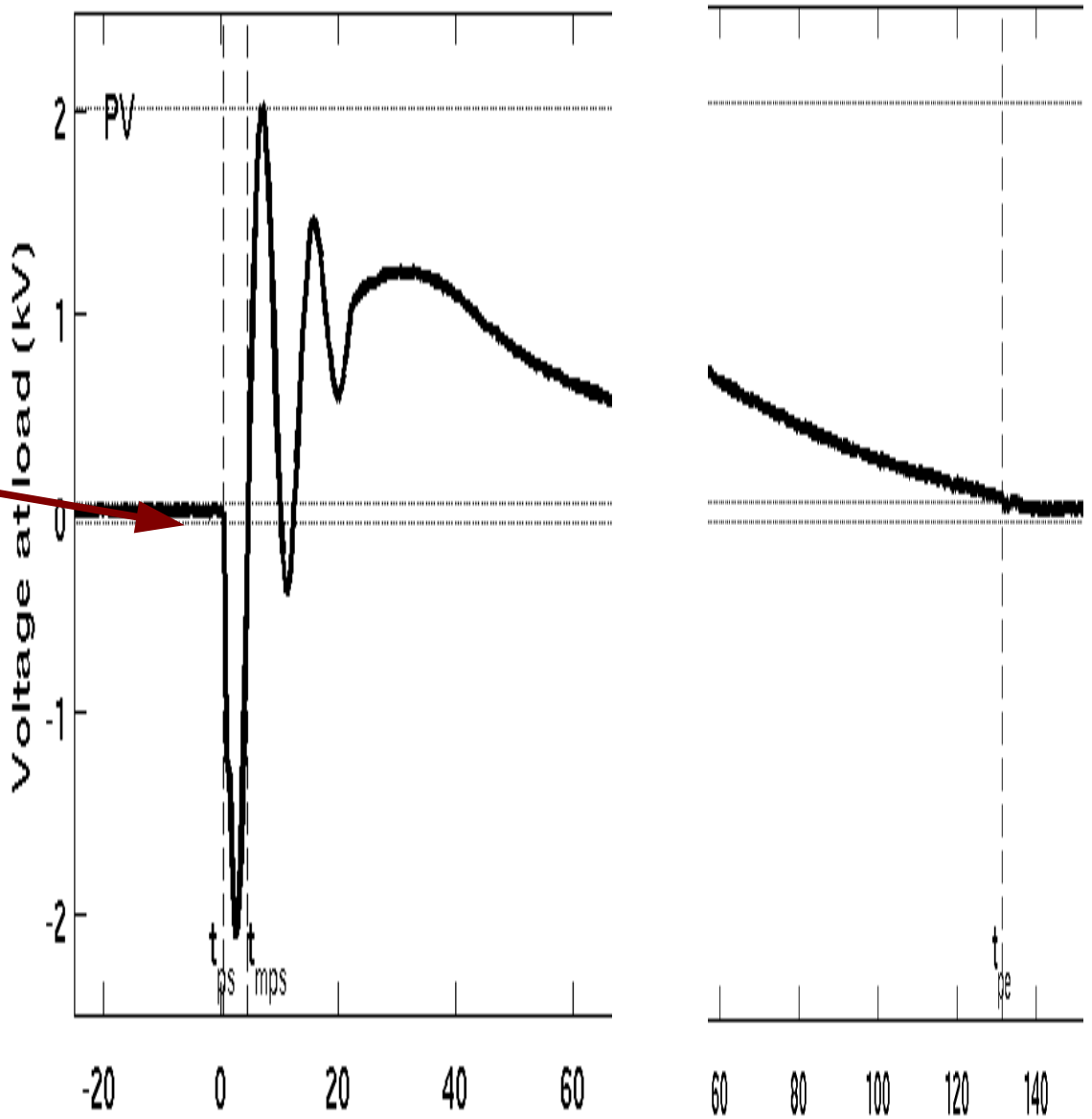


X26 Taser: Pulse parameters

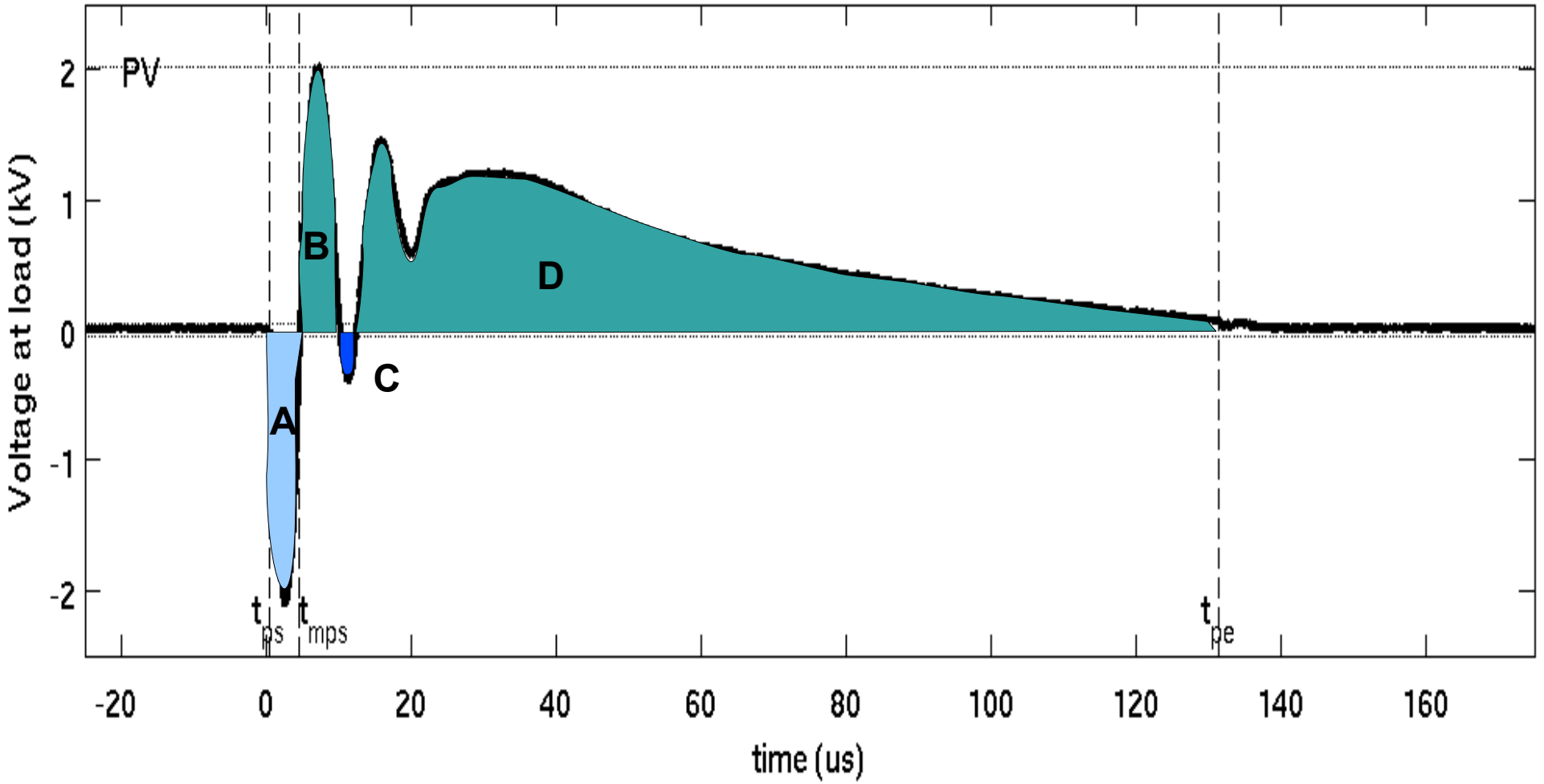
Pulse timing:
start and end of
pulses is defined
at the crossing of
the ±50V threshold

It is recommended to
use a digital filter to
reduce uncertainty of
the threshold cross
point.

Example: a phaseless
1MHz Butterworth filter



X26 Taser: Pulse parameters

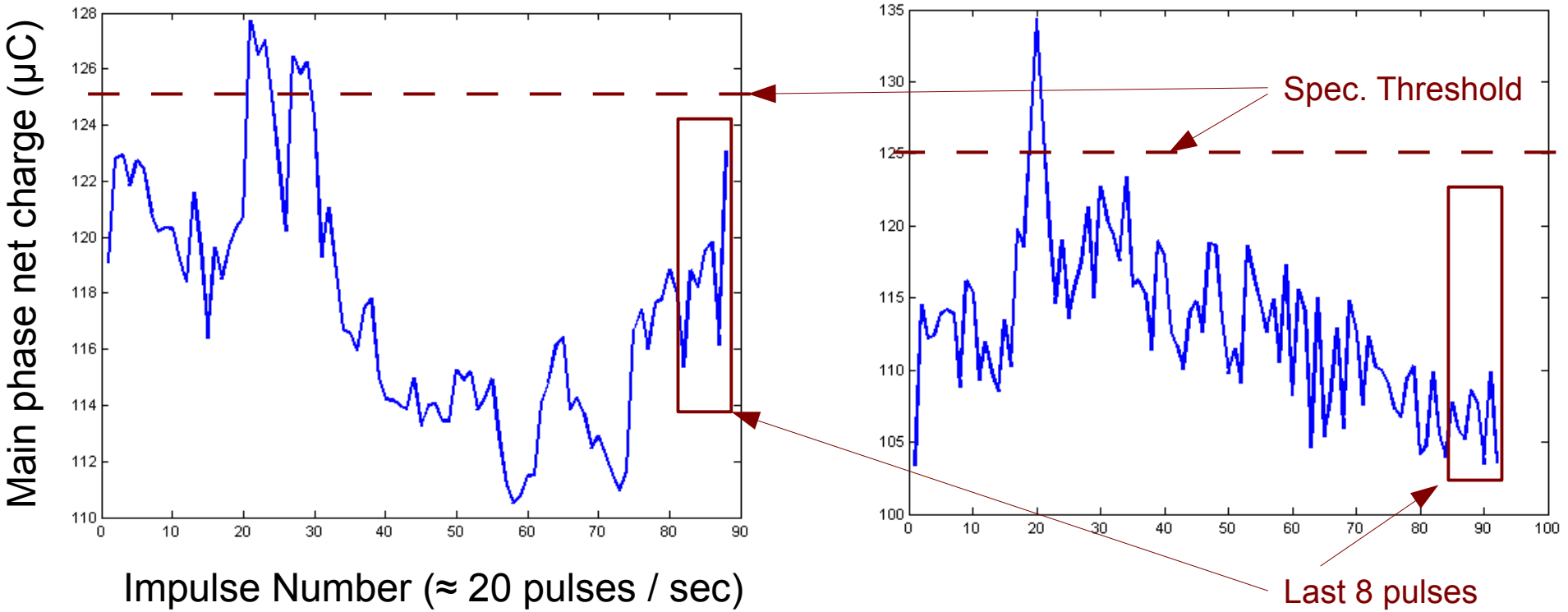


Full Pulse Total Charge = A + B + C + D
Main Phase Net Charge = B – C + D

Comment: Total charge / Net Charge

- Nomenclature issues:
  - Many different “full” and “net” charges have been defined. MPB uses “full pulse total charge” and “main phase net charge”
  - DECISION: *Use terms in MPB “tests concepts documents”*
- Scientific issues:
  - Some literature uses total charge (sum of abs. value of pulses)
  - Some literature uses charge in largest phase
  - DECISION: *Store both.*
- General standard (not X26 specific)
  - Definition of Net Charge (B-C+D) is only for X26
  - DECISION: *Standard will need editing for other CEWs*

Variability of pulses



- Both weapons are within TI spec [1]
- We propose a spec on the maximum pulse

C: Data Analysis: *summary data*

- Summary data example (for each firing):

Summary	MAX	MIN	AVG	AVG-8	STD
Full Pulse Total Charge (µC)	123	108	115	113	8.3
Main Phase Net Charge (µC)	119	105	111	109	11
Pulse Duration (us)	131	116	128	126	3.5
Interpulse Time (ms)	62.0	49.2	54.3	55.9	5.7
Peak Voltage (V)	2094	1861	1938	1923	80.3
Peak Current (A)	3.52	3.13	3.26	3.23	0.15

How many significant figures: based on hardware accuracy, but at least 3 figures given 0.5% accuracy minimum (ie. 8 bit) specs

Values in the Feb 4, 2009 Spec from Taser Int.

Idea: New parameter: F_T

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Dosimetry considerations for electrical stun devices

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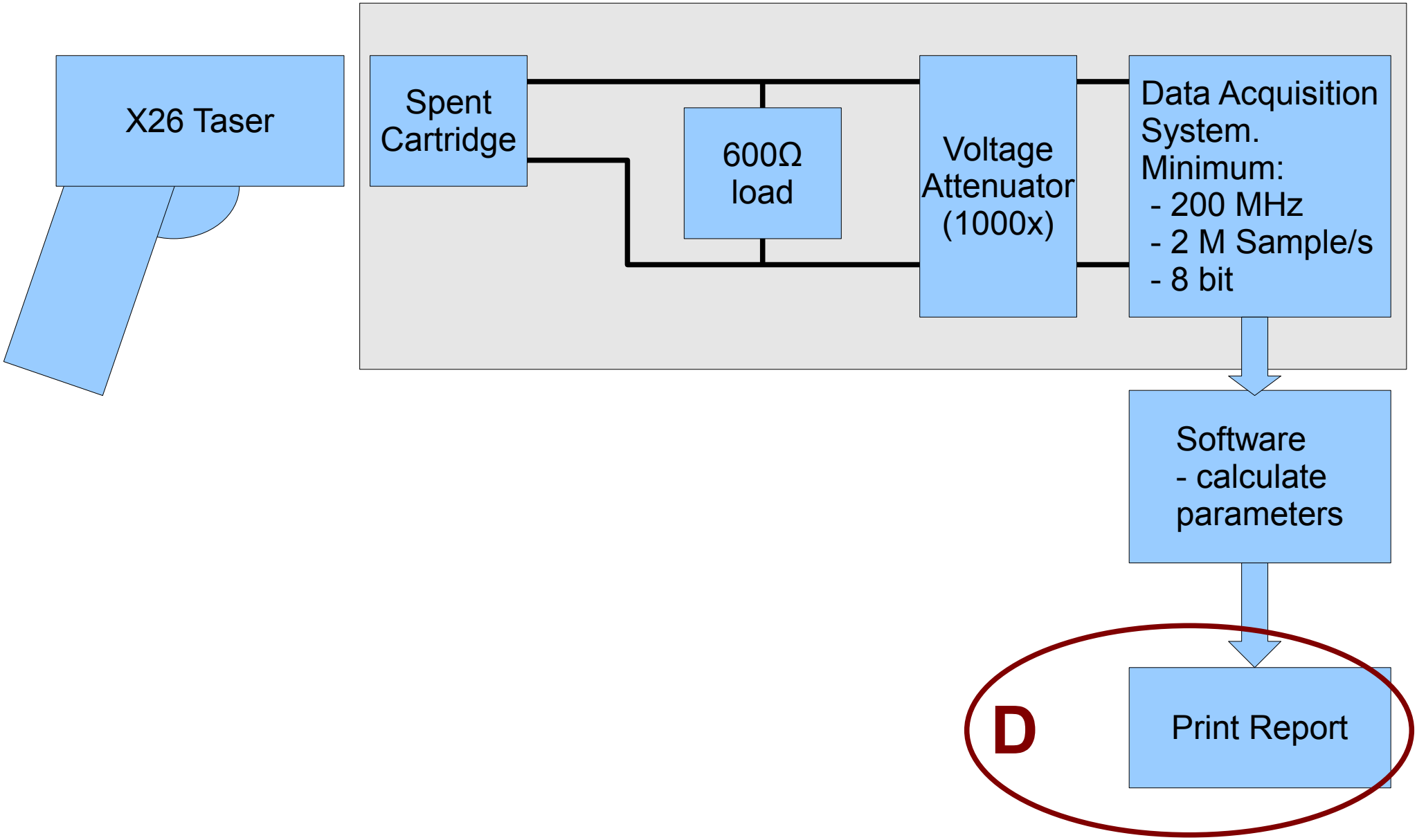
Abstract
Electrical dosimetry issues are discussed in relation to electrical stun devices (ESDs). A measure of effectiveness is based on a 'threshold factor,' F_T, calculated with a myelinated nerve model that simulates stimulation of a reference-case neuron (20 μm diameter, 1 cm distant). Several ESDs were measured in the laboratory using resistive loads of 100–1000 Ω

New parameter: F_T

- JP Reilly is a bioelectrical safety expert (and key *Braidwood* witness).
- Developed new way to correlate stimulation dose across multiple devices
  - F_T = 1 is a strength that just stimulates nerve
  - F_T values is the number of times that strength
- Software to calculate is complicated, but discussion indicated he's interested in sharing software with us for this project.
- Propose: add to parameter list if get source SW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Spent Cartridge
600Ω load
Voltage Attenuator (1000x)
Data Acquisition System.
Minimum:
- 200 MHz
- 2 M Sample/s
- 8 bit
Software
- calculate parameters
D
Print Report

D: Reporting

- Indication: *Use* / *Don't Use*
  - Parameters in the AVG-8 for Firing #2 and #3 are compared to the specs from Taser International[1]
  - Specification on the maximum pulse
  - Additional specs to be developed
- The complete test document (next page) should be completed and sent to data repository
  - This characterization data will allow identification of weapon issues like poor serial numbers, failure modes, etc.

X26 Test Document: *Draft*

Conducted Energy Weapon Test Report	Date:
Weapon:	Serial Number:
Police Service:	Police Officer:
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Visual Inspection:	Case □ Battery □ Electrodes □ etc...
Comments:	*Example: changed battery, couldn't see display*
Software Version:	Battery Charge: Data download performed □

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M.P. Net Charge (µC)					
Pulse Duration (µs)					
Interpulse Time (ms)					
M.P. Peak Voltage (V)					
M.P. Peak Current (A)					
Pulse Rep. Freq. (Hz)					
Total Burst Length (s)					

Within Specifications: Yes □ / No □

New Safety Specs

#1 #2 #3

Data for Firings

Taser Int. Specs [1]

New Operational Specs

New Safety / Operational Specs

- New Safety Specs
  - Based on IEC:
    - Max: *F.P. Total Charge*
  - Based on multiple of TI [1]
    - Max: *M.P. Net Charge, M.P. Peak Voltage, etc.*
- New Operational Specs
    - Min/Max: *total burst length*

Characterization Data: *Comment*

- In order to adequately collect and use characterization data we need a data repository. This is like many others: transport, mining ...
- *National* Data repository:
  - All CEW weapons tests results should go here, so that trends can be identified.
  - Who runs it?
  - Who funds it?
  - How public are the data (to researchers, media)?

Summary

X26 Taser

Measurement System

Agreement on Hardware
Agreement on Software

Agreement on Contents
Format needs definition

Print Report

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Within Specifications: Yes □ / No □

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In spec. / out of spec.
(USE / Don't USE)

2. Data storage

Enable analysis for:
- Weapon lifecycle
- Predict malfunction
- Problem serial number
- Post-incident

Agreement:
- Use TI [1] + new safety and operational specs
- Add new specs based on research output

Agreement on data format
Data repository needs to be created and defined

Certification

- What we want:
  - Given this protocol, several companies can offer Taser test services to police organizations
- Advantage:
  - Competition will help improve prices and service
- Challenge:
  - To ensure conformance to test protocol
- Possibilities:
  - Standards association certification
  - Individual certification by professional engineers

Next Steps

- Seek consensus at this workshop ✓
- Look for input from other experts
  - Get public comments
- Write up in two forms:
  - Short: just the test protocol
  - Long: test protocol + justification (publish in scientific literature)
- Develop national data repository
- Develop certification approach