

1 Supplementary Material for *Cityscape Blast* –
2 *Partial Validation of CFD in a Complex*
3 *Environment*

4 Stephanie J Burrows^{*1}, Shaun A Forth¹, and Robert Sheldon²

5 ¹Centre for Simulation and Analytics, Cranfield University, UK

6 ²Centre for Defence Engineering, Cranfield University, UK

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8 **1 Method for calculating phase summary data**
9 **for experimental results**

10 As can be seen in the various overpressure time series plots in the attached
11 paper, the experimental data are relatively noisy, with short-timescale os-
12 cillations in the overpressure that are not present in the simulated results.

^{*}stephanie.j.burrows@cranfield.ac.uk

13 Because of these oscillations, a simplistic approach to determining the phases
14 in the experimental data (i.e. with a new phase beginning with each change
15 in sign) would produce significant differences between the arrival times for
16 the experimental and simulated results, despite relatively good agreement
17 between the overpressures at any given time. Because of this, an algorithm
18 was developed to identify the most significant trends in the overpressure time
19 series, allowing comparison of peak pressures and impulses between the ex-
20 perimental and simulated data for similar time periods. This algorithm is
21 described in this document.

22 As a measure of the significance of the various phases, the algorithm uses
23 the impulse; since the impulse is the overpressure integrated over time, this
24 measures both the height of the overpressure peaks and the duration during
25 which the overpressure maintained a specific sign. Each local maximum or
26 minimum in the impulse indicates where the overpressure changed sign; the
27 more prominent these peaks are, the more significant the phase is.

28 The impulse of the experimental time series is calculated using the `cumtrapz`
29 inbuilt MATLAB function, which numerically integrates a discrete time se-
30 ries using the trapezoid rule, with each entry in the resulting array being the
31 integrated value from the beginning of the time series up to the associated
32 point in time.

33 By comparing the simulated and experimental overpressure time series,
34 we determine a cut-off time, after which the experimental data are no longer
35 of interest. Experimental data after this cut-off time are discarded—this

36 helps to prevent including areas of the experimental time series where some
 37 of the pressure gauges were damaged and produced erroneous overpressure
 38 readings.

39 Next, all of the peaks in the impulse that have a prominence greater than
 40 a certain threshold are found, using the `findpeaks` MATLAB function. This
 41 is illustrated in Fig. 1. The threshold is set to a fraction, δ , of the maximum
 42 absolute impulse before the cut-off time. Typically, $\delta = 0.01$ produces arrival
 43 times that agree reasonably well with simulated results, and look plausible
 44 by eye. The times associated with these peaks are the arrival times for the
 45 phases.

46 The above algorithm works well for arrival times where the overpressure
 47 is changing sign, but it does not capture the arrival of the blast wave’s first
 48 phase, where the overpressure goes from near zero to a positive value. This
 49 time is characterized by a sharp change in the overpressure; as a result, the
 50 algorithm partially bases its selection of this arrival time on the change in
 51 pressure from one timestep to the next.

52 First, $\delta p_i = |p_{i+1} - p_i|$ is found. This is then used to set the threshold,
 53 $\Delta p = \epsilon \cdot \max(\delta p)$, where ϵ is an input parameter, which is typically set to
 54 0.1. The first phase arrival time is then the minimum time, t_i , where $t_i > 0$,
 55 $\delta p_i > \Delta p$ (ensuring the jump in p is at least 10% of the largest jump in p),
 56 and $p_i > -\Delta p$ (with the previous constraint, at least the *next* value of p is
 57 sure to be positive). In practice, this combination of constraints produces an
 58 arrival time that agrees well with simulated results, and is usually close to

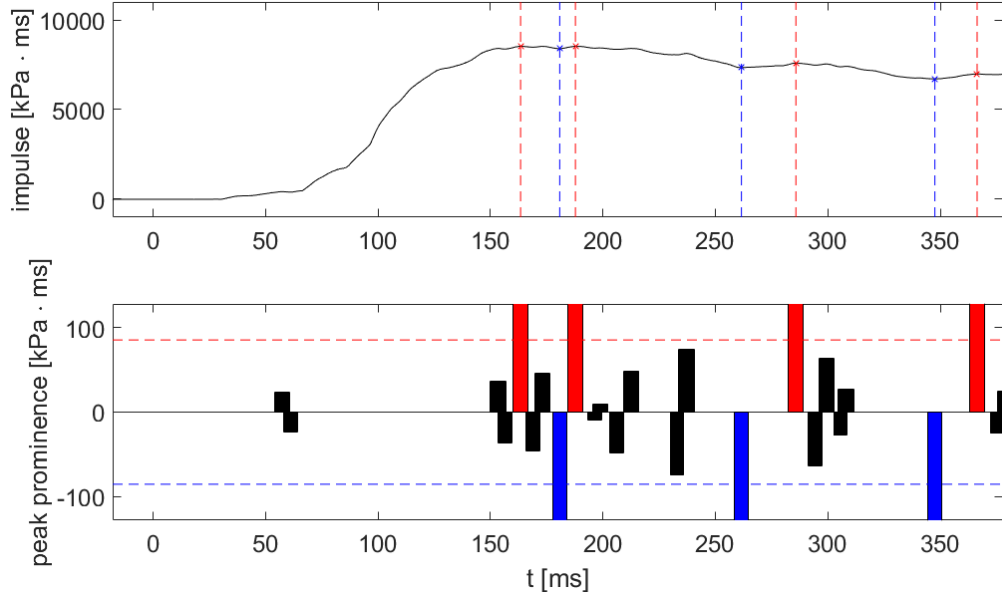


Figure 1: Peaks in the impulse at Q4. The top plot shows an impulse time series, with the most significant peaks marked in red, and the most significant troughs marked in blue. Only peaks with prominence over a certain threshold are chosen; although there are other peaks in the impulse, these do not have sufficient prominence to be considered the arrival time of a new phase. This is illustrated in the lower plot, where peaks and troughs *not* satisfying the prominence threshold are shown in black.

59 the value one would determine by visual inspection of the overpressure time
 60 series.

61 Although finding prominent peaks in the impulse typically does *not* find
 62 the start of the first positive phase, occasionally, noise in the overpressure
 63 time series means that the first phase arrival time *does* appear as a peak

64 in the impulse. This means that combining the arrival times from this al-
65 gorithm with the arrival time found using the algorithm described in the
66 previous paragraph can produce duplicates. These are removed by sorting
67 the arrival times in order, and removing those where the number of mea-
68 surements between that time and the next is less than a certain threshold
69 (typically set to 5). These are usually genuine duplicates, and not very short
70 phases.

71 Some of the pressure gauge measurements exhibit large oscillations in the
72 overpressure before the simulated arrival of the initial blast wave; we believe
73 that these are due to vibrations travelling through the buildings themselves.
74 While our algorithm attempts to account for this type of noise, in some cases,
75 the oscillations are nearly as large as those from the blast wave itself. To
76 ensure comparison against similar time periods between the simulated and
77 experimental results, the closest phase arrival time to the simulated phase 1
78 arrival time for the finest grid resolution available is selected and this is said
79 to be the beginning of phase 1 in the experiment. This works well for all of
80 the experimental results, apart from Q6, which is discussed in the paper.