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# Timing Aerial Shell Bursts for Maximum Safety and Performance

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The time chosen for the interval between a shell firing and its burst is sometimes given less thought than it deserves. By carefully choosing the delay interval provided by the time fuse, it may be possible to produce undistorted bursts, with a higher level of safety.

When an aerial shell bursts, while it is nearly stationary, its stars are propelled outward, each experiencing nearly the same aerodynamic drag. Thus the symmetry of the burst is determined only by the construction of the shell, and the pattern will appear to be suspended in the air for its duration. That is to say, a properly made peony will appear as an expanding, near-perfect sphere and will seem to hang motionless in the air as it spreads. See the left column of Figure 1, which is intended to appear as a timed sequence of the burst and expanding pattern of stars from a near stationary spherical shell. On the other hand, if the same shell were to burst while it was in rapid motion, the star pattern would be distorted. This is because the spreading stars would be subjected to a little different aerodynamic force depending on which way they were traveling relative to the motion of the shell. The star pattern will appear smaller and somewhat elliptical. Also the star pattern will be slightly more sparse on the bottom than on the top. Perhaps, most noticeably, the developing star pattern will move in the direction of the original shell motion, and will appear to expand from a point which is not at the center of the pattern. See the right column of Figure 1 for an illustration of the case where the upward motion of the shell approximately equals the burst velocity of the stars. (Readers wishing to learn more about star ballistics are referred to Reference 1.) Thus there are aesthetic reasons why aerial shells are normally intended to burst near their apogee, when their upward motion has essentially stopped.

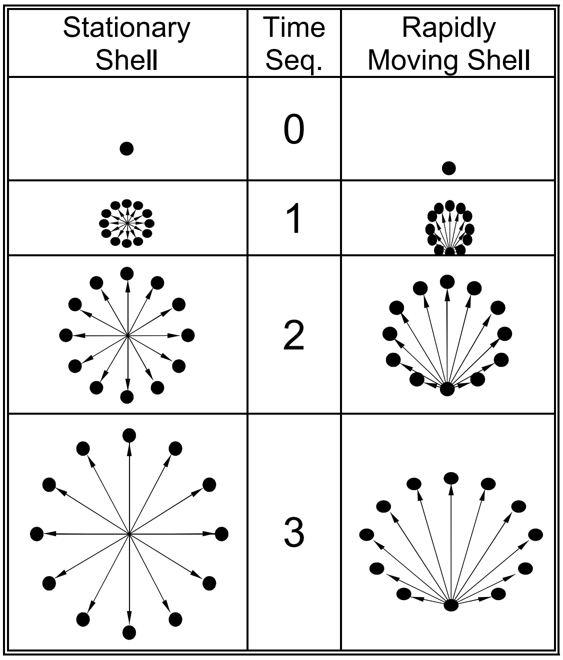


*Figure 1. Time sequence views of stationary and rapidly moving aerial shell bursts.*

The time interval during which the vertical motion of an aerial shell has virtually stopped is longer than many may realize. Aerial shells spend more than four seconds traveling up and down only 70 feet at their apogee, and this is independent of shell size, see Figure 2. These results were generated using the computer model described in an earlier article.[2] This illustrates the trajectory of typical 3, 6, and 12-inch aerial shells fired from slightly angled mortars, where the time elapsing between each point is one second. The plotting of the shell trajectory data is terminated a few seconds after the shell's apogee.

**Table 1. Input Parameters and Results of Computer Modeling.**

| Nominal Shell Size: | 3" | 6" | 12" |
|---|---|---|---|
| Input Parameters: | | | |
| Shell shape | Spherical | Spherical | Spherical |
| Shell Diameter (inches) | 2.75 | 5.56 | 11.50 |
| Shell Weight (pounds) | 0.3 | 2.5 | 18.0 |
| Drag Coefficient[a] | 0.40 | 0.37 | 0.31 |
| Muzzle Velocity (ft/sec) | 300 | 340 | 360 |
| Results: | | | |
| Apogee Height (feet) | 440 | 760 | 1100 |
| Time to Apogee (seconds) | 4.5 | 6.0 | 7.6 |
| ± 70 ft Time Interval (sec) | 4.1 | 4.2 | 4.2 |
| Approx. Ideal Burst Times (sec) | 2.5–3.0 | 4.0–4.5 | 5.5–6.0 |
| Experimental Burst Height (ft)[b] | 406 ± 50 | 776 ± 52 | 1164 ± 134 |

[a] Empirically determined from published data.[2]
[b] Experimentally determined aerial shell burst heights were reported earlier.[3]

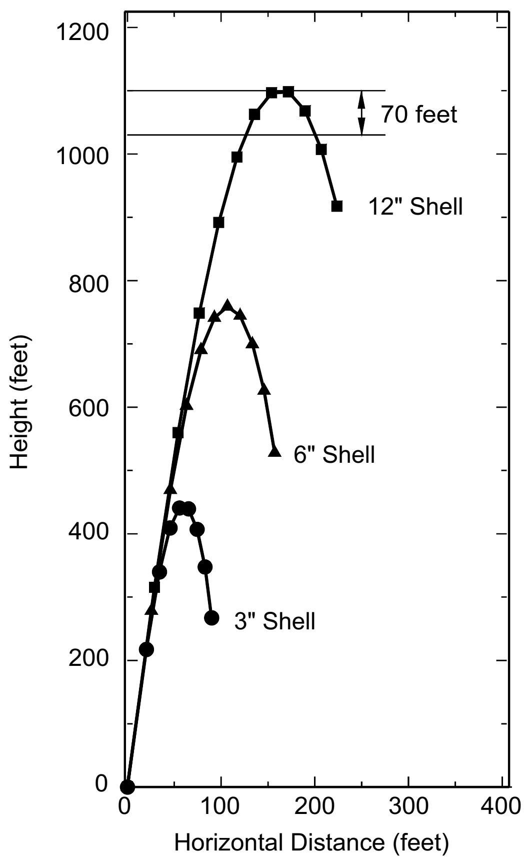


*Figure 2. Trajectories of spherical aerial shells illustrating the approximate 4-second, near-stationary, interval about the apogee.*

Table 1 presents the input data for the computer model, as well as, the results. Included in the results is the approximate time for the shell to travel up and then back down the last 70 feet about its apogee. In each case, this time is about 4.2 seconds, independent of shell size. Thus it is relatively easy to time the burst of an aerial shell to occur during this 4-second period. In terms of fullness and symmetry of the star pattern, because the shell is moving so slowly during this interval, a burst at any time is equivalent. In terms of safety, however, all times are not equivalent. If the burst is planned to occur at or near the start of this interval, there will be added time to allow a damp or sputtering time fuse to complete its task before the shell falls too close to the ground for its stars or components to burn out before endangering people or property. Similarly, on those occasions when shells are mistakenly fired from over-sized mortars, the amount of burning debris reaching the ground will be lessened if the shell has been designed to burst early during the 4-second interval about its intended apogee.

Thus, by selecting the time-fuse delay (length) so that bursts occur 1.5 to 2.0 seconds prior to apogee, safety may be increased without loss in aesthetic performance. These times are included in Table 1 as approximate ideal burst times for the stated input parameters. Obviously, the actual time delays need to be determined by experimentation and will depend on individual shell and mortar parameters.

**References**

1) T. Shimizu, *Fireworks from a Physical Standpoint, Part III*, Pyrotechnica Publications, Austin, TX, 1985.

2) K.L. and B.J. Kosanke, "Aerial Shell Ballistic Computer Modeling", *Pyrotechnica XIV*, Pyrotechnica Publications, Austin, TX, 1992.

3) K.L. Kosanke, L.A. Schwertly and B.J. Kosanke, "Report of Aerial Shell Burst Height Measurements", *PGI Bulletin* No. 68, 1989.