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Low-Yield Nuclear Explosion Calculations: The 9/22/79 VELA Signal (U)

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LOW-YIELD NUCLEAR EXPLOSION CALCULATIONS: THE 9/22/79 VELA SIGNAL (U)

by

E. M. Jones, R. W. Whitaker,
H. G. Horak, and J. W. Kodis

ABSTRACT (SRD)

DOE b(1)

Normally, independent confirming evidence is available from other VELA satellites and other sources. Unfortunately, such confirming evidence has not been uncovered for the 9/22/79 event.

DOE b(1)

In this report we summarize the Vela data, discuss classical interpretations, and present a particular model which, we believe, satisfactorily reproduces the Vela signal.

DOE b(1)

Thus, our model is consistent with the apparent absence of nuclear debris, the collection of which is required by some analysts for absolute confirmation of an atmospheric detonation.

I. THE VELA DATA

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The VELA satellite and its detectors are described elsewhere (e.g. Horak 1980). For our purposes, the salient features of the detections system are

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(5) that the instrument response is discrete both in time and in level. The bottoms of adjacent levels are separated by a logarithmic interval.

DOE b(1)

where D is irradiance. The time spacing is somewhat more complex but is basically logarithmic;

(6)

DOE b(1)

The VELA data for the 9/22/79 event are given as irradiance in watts per centimeter squared versus time in milliseconds on the left-hand scale and LD (Level Discriminator) levels on the right-hand scale of Fig. 1. Uncertainties are of the order of one LD level.

Table I lists our best estimates of the times (t) and irradiance levels (I) at first maximum (1-max), minimum (min), and the second maximum (2-max) from each of the detectors. The uncertainties are estimated.

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II. SCALING LAWS FOR ATMOSPHERIC NUCLEAR EXPLOSIONS

Our purpose is to determine the parameters of an atmospheric nuclear explosion that best fit the data

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observed by the VELA satellite. As a first step, we use classic scaling laws to estimate the significant parameters of yield and burst height density; then we discuss computer calculations chosen to provide more precise estimates of the explosion parameters.

Numerous sets of scaling laws exist. Here, we have synthesized four adequate scaling laws from discussions by Zinn et al. (1974) and Sappenfield (1979).

As we shall see, the time of first maximum and the power ratios are inconsistent with the other observations. Solving the puzzle will concern most of the rest of our study.

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DOE b(1)

Clearly, conventional scaling laws cannot provide a consistent model for the VELA data.

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The values of the observable quantities ($t_{1\text{-max}}$, $t_{2\text{-max}}$, and $P_{2\text{-max}}P_{min}$) have large uncertainties.

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Both Y and ρ are model independent because they are the basic parameters of any calculation. The other three factors can vary dramatically among different models. Let us now consider these other factors and discuss how they can affect the signal.

Cloud cover, atmospheric absorption, and scattering by particulates between the explosion and the satellite can alter the interpretation of the signal. Atmospheric transmission must be considered when deriving radiance at the source from the observed irradiance. However, simple absorption by the atmosphere will not produce dramatic shifts in the timings of events in the signal nor, to first order, will it depress one part of the signal relative to another. However, cloud cover can introduce time smearing caused by photon scattering. Multiple photon scatterings can delay first maximum but should also depress the signal in both peaks. The observed irradiance levels are high enough that the signal could not have suffered much absorption nor scattering beyond that expected for relatively clear maritime air. We do not believe that the data supports the contention that there was any significant modification of the signal by the atmosphere or by clouds.

Nuclear weapons with significant neutron output can create an obscuring curtain of "smog" (principally NO_2, HNO_2, and O_3). As discussed by Zinn et al. (1974), smog may produce not only a delay in first maximum but also a severe depression of the first pulse by absorption. The minimum and second maximum usually are unaffected by smog because the fireball radius at these times exceeds the distances at which significant neutron deposition occurs.

DOE b(3)

DOE b(1)

Perhaps the most dramatic mass effect has been known since the earliest days of atmospheric testing: the *apparent yield* of a burst at the earth's surface (land or sea) is twice the actual yield. The reason is simply that the surface acts as a nearly perfect reflecting plane. The entire explosion energy acts only in the hemisphere above the surface as if the surface were absent and we were witnessing the spherical expansion of a higher yield explosion. The result is that the radiative/hydrodynamic behavior is identical to that of a free-air burst at twice the actual yield. Among others, Sappenfield (1979) has reviewed the empirical evidence supporting this result.

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The hydrodynamic behavior and the power-time curve of this case are illustrated in Figs. 3 and 4, respectively.

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DOE b(3)

During radiative expansion, the fireball brightness depends primarily on the surface area, and the power output increases monotonically. Several bomb masses of air are engulfed during this phase. However, after formation of the air shock at the fireball edge, the brightness depends on the shock speed as well as on the surface area.

DOE b(3)

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Fireball growth is slowed and, more important, areal emission decreases rapidly. The fireball brightness begins to drop when first maximum has been passed.

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"he rest of this report discusses the effects of mass on the complete optical signal.

III. RADFLO CALCULATIONS

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For our present purposes, we have chosen to do calculations in which the nuclear explosive is modeled as a sphere of high-density air at uniform density. The "air bomb" comprises the 10 innermost cells in the calculational grid.

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In each calculation, a certain fraction of the explosion energy is deposited as internal energy at t = 0 in the central cell.

DOE b(3)

What matters here is the kinetic energy content of the debris, which is largely insensitive to the material composition.

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The principal results are tabulated in Tables II and III.

The effect of M and ρ on the times of minimum and of the two maximums are shown in Figs. 7-9. The choice of a time value from a calculation or from data is subjective.

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DOE b(3)

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The cause of this minimum or its reality is unknown.

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Zinn et al. (1974) show a strong $t_{2\text{-max}}$ dependence on density. Their result is confirmed by our calculations.

[redacted]

These scaling laws [Eqs. (6)-(8)] can be used to refine our estimates of the explosion parameters. The very weak density dependence and the large timing uncertain- ... st that we cannot derive a dependable density

[redacted]

we can choose ρ [redacted] We return to a discussion of burst height effects in Sec. IV.

We can now derive a yield and mass from our scaling laws

[redacted]

Figure 9 shows the band of permitted values in the (Y,M) plane. The $t_{1\text{-max}}$ scaling law [Eq. (6)] seems to give a slight overestimate of $t_{1\text{-max}}$ at high masses.

[redacted]

As a final check on the explosion parameters, we note their effect on the power ratios $P_{2\text{-max}}/P_{1\text{-max}}$ and $P_{2\text{-max}}/P_{min}$ as shown in Figs. 10-12. The ratio of maximums $P_{2\text{-max}}/P_{1\text{-max}}$ appears to have only slight sensitivity to mass and ambient density.

[redacted]

The ratio $P_{2\text{-max}}/P_{min}$ is a strong function of mass, yield, and density.

[redacted]

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IV. A MODEL FOR THE 9/22/79 BURST (ALERT 747)

[redacted]

The predicted power-time curve is shown in Fig. 12. This is a time-averaged curve.

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DOE b(3)

(12)

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[redacted] The agreement is satisfactory.

After the shock emerges from the bomb and begins to sweep up ambient air, the power-time curve shows dramatic oscillations produced by the entrainment of individual calculational cells. When the shock first encounters an ambient cell, the air temperature in the cell rises, causing the opacity to rise and thereby decreasing fireball brightness. Eventually, the newly entrained cell is heated enough that it starts radiating, and the fireball brightness increases until the cycle is repeated with the entrainment of the next cell outward. Interpretation of the calculated power levels during the first pulse is uncertain. We have chosen to show the power levels averaged over each cycle as

$$\bar{P} = {}_{\delta t}\int_{\text{cycle}} P \, dt \qquad (13)$$

DOE b(3)

[redacted]

[redacted] The calculated amplitude of the bump at high mass is well below the data uncertainties.

At later times, physical mechanisms responsible for producing the power-time curve variations are well understood. The interested reader may consult Zinn (1973), Zinn et al. (1974), Brode (1968), or Glasstone (1964) for discussions of phenomena at t_{min} and beyond.

We have plotted our best interpretation of the VELA data to produce the power outputs in Fig. 12.

[redacted]

DOE b(3)

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V. PERTINENT DATA FROM ATMOSPHERIC NUCLEAR TESTS

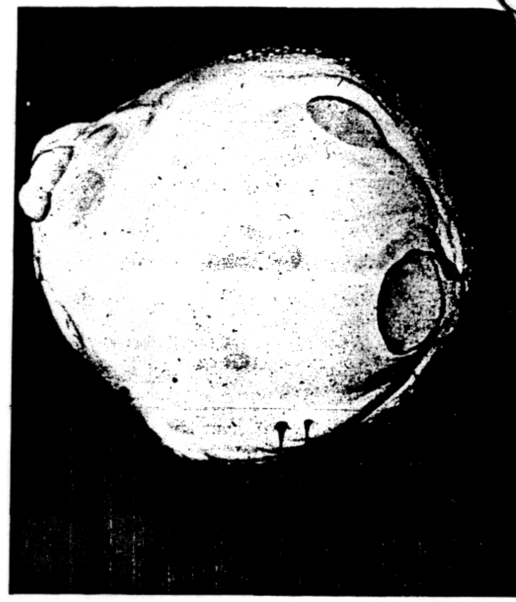
We have constructed what we believe to be a plausible model for a low-yield nuclear explosion that could have duced the observed Alert 747 signal.

In this section, we examine the available data for t_{1-max} from atmospheric nuclear tests.

The available t_{1-max} data are plotted as a function of yield in Fig. 13. We note that for many events of the US atmospheric test program, data pertinent to the first maximum are not available.

However, the fit after about ms is quite satisfactory

*Personal communication to authors.



GEORGE was detonated atop a tower 61 m above Eniwetok on May 9, 1951.

Two features in the explosion phenomenology are of interest. First, the fireball expansion was very asymmetric during the early phases; second, independent determination of the yield by hydrodynamic and radiochemical techniques were widely discrepant.

The other part of the fireball may have grown radiatively. Clearly, calculational studies in two or three dimensions will be required to provide a convincing explanation.

At later times, the expansion becomes more symmetric and, at minimum, this fireball has prominent spots.

The hydrodynamic yield is determined by comparing the radius-time data with the expectations of classic blast wave theory. In particular, during the period immediately preceding minimum, the quality

(16)

is virtually constant. In Fig. 16, we show the ϕ histories obtained from four RADFLO calculations compared

[redacted]

DOE b(3)

VI. CAVEATS

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[redacted] with the GEORGE data. These data were derived by visually estimating a "best-circle" fit to the fireball shape. [redacted] Nonetheless, we recognize that we have made certain assumptions that, if proved wrong, may alter our conclusions.

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(2) We have used dense air to model the weapon vapor.

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DOE b(3)

We have been unable to secure experimental confirmation of a $t_{1\text{-}max}$ delay caused by mass.

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The possibility remains that other models can produce good fits to the data. Proponents of such models must demonstrate plausibility.

VII. SUMMARY

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*Private communication to authors.

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