# MODELING THE ENTRY DYNAMICS, LINE SOURCE WAVE NORMAL PATHS AND ATMOSPHERIC PRESSURE WAVE SIGNATURES FROM THE CARANCAS METEORITE FALL.

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**Introduction:** We have modeled the Carancas meteorite fall of September 15, 2007 (an official H4-5 type or an ordinary chondrite from the H group that is a breccia of type 4 and type 5 components) using several complimentary approaches.

**Entry Dynamics and Energetics Modeling:** Two types of entry dynamics and energetics models have been applied to this unusual event, namely a top-down, direct approach [1-3] as well as a bottom-up, inverse entry modeling approach [4, 10]. Both methods require different parameters to be input during the analyses. For example, the direct approach requires inputs of initial size, shape, mass, entry angle, specific atmospheric properties as well as the meteorite bulk density, etc., whereas the bottom-up approach requires values at impact to be used to predict the entry parameters at the top of the atmosphere. We use these two complimentary approaches in unison to narrow the possible range of entry properties (velocity, radius, blast wave relaxation radius, entry angle, etc.) for this very puzzling meteorite fall and associated crater event. The limiting minimum value of the blast wave radius in the absence of fragmentation effects is approximately given by the product of the Mach number (the characteristic speed along the trajectory divided by the local adiabatic thermodynamic sound speed) times that body diameter at any height. From numerous simulations, many allowing for fragmentation and the size of the crater that was made in the high altitude mountains of northern Peru, we have deduced that it is likely that the Carancas meteorite entered fairly steeply with quite low velocity, was quite small and thus had a small initial kinetic energy ($< \sim 0.10 - 0.50$ kt; 1 kt = $4.185 \cdot 10^{12}$ J).

**Line Source Wave Normal Paths:** We have also used these entry simulations to predict propagation paths of infrasonic (subaudible) line source blast waves [1, 3] from our most probable entry dynamics solutions starting from a distance of ten blast wave radii from the trajectory. In this analysis, in order to avoid complications of the proper phase alignment of the wavefronts, we have assumed steady state solutions for various bolide entry velocities based upon solutions found earlier with the entry model approaches. The predicted Mach cone for example is fairly broad (open) at these lower entry velocities and the associated line source wave normal tracing efforts predict a set of complex paths for source altitudes from 20-70 km for example. This type of analysis also allows us to predict arrival properties at relatively close ranges (azimuth, trace velocity or the elevation arrival angle, onset times of various phases, etc.). These properties can also be compared to the measured ones recorded at the seismic sensors and infrasound arrays that detected this event.

**Atmospheric Pressure Wave Signatures:** Finally, we have also developed a numerical computer code (in Cartesian coordinates) that can be used to model the pressure wave signatures of atmospheric waves (for periods from ~3 hr to 0.10 s) produced by bolides and that has been currently applied to the Carancas meteorite fall and entry. This work is a significant extension of work previously published and also additional work presented at Meteoroids2007 [5-9]. The extended version of this approach will also be presented at the 2008 Baltimore ACM conference. Infrasonic (subaudible) detections were made at two IMS (International Monitoring System) arrays (I08BO in Bolivia at quite close range and I41PY in Paraguay some 1560 km away). Our detailed analyses of waves arriving at both of these arrays will be presented and related to the source properties (source heights, source energy, etc.).

**References:** [1] ReVelle, D.O. (2004) *Earth, Moon and Planets*, **95**, 441-476. [2] ReVelle, D.O. (2007) in *Near-Earth Objects*, IAU Symposium **236**, Editors, A. Milani, G.B. Valsecchi and D. Vokrouhlicky, 95-106. [3] ReVelle, D.O., Brown, P.G. and Spurny, P. (2004) *Meteoritics and Planetary Science*, **39**, 1-22. [4] ReVelle, D.O. (1979) *JASTP*, **41**, 453-473, [5] Edwards, W.N., Brown P.G. and ReVelle, D.O. (2006) *JASTP*, **68**, 1136-1160. [6] Edwards, W.N., Brown, P.G., Weryk, R. *J.* and ReVelle, D.O. (2008) *Earth, Moon and Planets*, **102**, 221-229. [7] ReVelle, D.O., Sukara, E.A., Edwards, W.N. and Brown, P.G. (2008) *Earth, Moon and Planets*, **102**, 337-344. [8] Arrowsmith, S.J. and ReVelle, D.O. (2008) *Earth, Moon and Planets*, **102**, 357-363. [9] ReVelle, D.O. (2008) Earth, Moon and Planets, **102**, 345-356. [10] Brown et al. (2008) *JGR*, submitted.