CHARACTERISTICS OF A BRIGHT FIREBALL AND METEORITE FALL AT BUZZARD COULEE, SASKATCHEWAN, CANADA, NOVEMBER 20, 2008. A. R. Hildebrand[1], E. P. Milley[1] , P. G. Brown[2], P. J. A. McCausland[2], W. Edwards[2], M. Beech[3], A. Ling[4], G. Sarty[5], M. D. Paulson[4], L. A. Maillet[1], S. F. Jones[1] and M. R. Stauffer[5]. [1]Department of Geoscience, 2500 University Drive NW, University of Calgary, Calgary, AB T2N 1N4 (ahildebr@ucalgary.ca, epmilley@ucalgary.ca), [2]Department of Physics and Astronomy, The University of Western Ontario, London, ON, N6A 3K7, [3]Department of Physics, Campion College at the University of Regina, Regina, SK S4S 0A2, [4]Edmonton Centre, Royal Astronomical Society of Canada, [5]Departments of Physics and Engineering Physics and Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK S7N 5E2.

Introduction: A bright fireball was widely observed across Alberta, Saskatchewan and Manitoba during late twilight on November 20, 2008. Interviews of eyewitnesses and crude calibrations of security cameras constrained the fall region and the first search attempt recovered meteorites off the ice of a manmade pond in Buzzard Coulee, SK, Nov. 27, 2008.

Trajectory and Pre-fall Orbit: The fireball and subsequent dust trail, or shadows cast by the fireball, were widely recorded by all-sky (4) and security video cameras (at least 19) establishing that its brightest portion occurred from 17:26:40 to 17:26:45 MST. The fireball traveled north to south with an elevation angle of ~67˚, and enough data are believed available to refine the trajectory to within 100's of m. The meteoroid had a low initial velocity indicating a low inclination pre-fall orbit resulted in this trajectory, and sufficient data are believed to exist to well constrain the orbit.

Fragmentation. The fireball fragmented multiple times during its atmospheric passage with significant fragmentation continuing deep within the atmosphere to ~12 km altitude based upon video records [Fig 1]. Three large fragments were digitally recorded continuing to still lower altitudes (implying that three particularly large meteorites may have fallen), and proximal eyewitnesses described a shower of red fragments continuing possibly within 5 km of the ground surface.

Meteorites and Fall Recovery: Buzzard Coulee is an H4 chondrite at the low end of the thermal range [1]. After the initial meteorite recovery subsequent organized searches and the alerted public recovered more than two hundred individual fragments (totaling ~50 kg) before December 6th when increasing snow cover made further searching unproductive. A strewn field ~10 kilometers long and ~3 km wide with a wind drift tail of an additional ~3 km eastwards has been crudely outlined. Recovered meteorites mass from <1 g to 13.1 kg. The surface density of meteorites based upon the discovery pond is ~20/hectare in the uprange part of the strewnfield implying ~2,000 meteorites (>10 g in mass) per km^2 in this area; the mass density is ~100 kg/km^2 and implied total mass >10 g in size is 1 to 2 tonnes. The meteorites are distinguished by the large number of specimens with immature ablation surfaces (angular shapes with numerous small piezoglypts) presumably reflecting the meteoroids' significant fragmentation extending deep into the atmosphere; a larger proportion of mature ablation surfaces and oriented individuals may occur up range in the strewn field. Fusion crusts are a typical dark gray for an ordinary chondrite fall with more vitreous crusts on the back of some oriented specimens. The fall is also distinguished by the large proportion of meteorites that exhibit freshly broken surfaces with no fusion crust; broken surfaces with variable amounts of "painting" by fusion crust are also common. Individuals with immature and mature surfaces and widely varying sizes are mixed on the ground presumably reflecting the extended fragmentation of the meteoroid.

Internal Structure: Numerous fresh broken surfaces on different meteorites generally show no brecciation textures, but one surface shows a slightly lighter gray angular clast in a uniform gray matrix. The larger fragments all have tabular shapes and freshly broken surfaces that show poorly to moderately well developed slickensides, and minor ~1 mm-wide veins or fracture coatings infrequently occur in some specimens. The general lack of veins and brecciation is consistent with the relatively low S2 shock state [1]. Densities measured on six specimens span 3.26 gcm^{-3} to 3.45 gcm^{-3} typical for an H chondrite [2] with some evidence for a bimodal distribution, which would be consistent with petrographic evidence for two lithologies within the meteorite [1].

Sonic Phenomena: Abundant sonic phenomena were reported by witnesses including anomalous sounds, explosion booms, staccato cracks, and late-stage whirring sounds. The staccato cracks are interpreted as closely spaced arrivals of discrete sonic booms from individual fragments while the latter were still supersonic in the early portion of their dark flight; this type of sound was reported only within ~50 km of the fall. The whirring sounds were reported only within ~20 km of the fall and are interpreted as produced by individual rotating fragments falling to ground while in subsonic dark flight. The two largest fragments recovered to date are both broken tabular slabs consistent with such strong sounds. Similar late-stage, whirring sounds have been reported for other falls ([e.g. 3], but not to such large distances. To the best of our knowledge, no persons were located outside in the strewn field (which is sparsely populated tilled fields and pasture) when the rocks were striking the ground, so "landing thud" reports are expected.

Infrasound. Infrasound signals from the fireball were recorded on microbarometers throughout North America. At least six North American stations (Fig 2) detected signals from the fireball, including three from the International Monitoring System of the Comprehensive Test Ban Treaty Organization. Propagation of infrasound from the fireball was dominated by a very strong easterly-directed stratospheric jet stream having wind velocities in excess of 50 m/s. This unusually strong jet produced strong directional variations in the infrasonic amplitude. At I10CA in Lac du Bonnet, MB, multiple signal paths and a very strong stratospheric arrival (Fig 3) were detected. The complex arrivals at some stations are likely a combination of the fireball source function and propagation pathways. These signals likely originated in the fragmentation events. The rich waveforms from many stations offer the prospect for the first time of resolving which portions of the trail produce signals at which stations with detailed ray trace modeling. We expect the dominant periods of the waveforms to be less affected by the strong wind systems than amplitudes and indeed find that the stratospherically ducted peak frequency measured at each of the three calibrated IMS stations are all consistently near 0.32 Hz. Using this measurement and the energy-period-yield relation given by [4] we find a best infrasonic energy estimate of the source of 0.32 ± 0.09 kilotons. This energy yield implies an entry mass of ~15 tonnes for the meteoroid.

Summary: The Buzzard Coulee meteorite fall allows calibration of video and infrasound fireball records (and eyewitness accounts) with a dense strewn field, and determination of a pre-fall orbit for a large H4 meteoroid. A new generation of digital security cameras may make orbit determination possible for an increasing proportion of falls.

References: [1] Hutson, M.L, et al., (2009) *this volume.* [2] Consolmagno, G.J. & Britt, D.T., (1998) *MPS., 33,* 1231-1241. [3] Brown, P.G. et al. (1996) *MPS., 31,* 502-517. [4] Revelle, D. (1997) *Ann N Y Acad Sci, 822*. [5] Borovicka, J & Jenniskens, P. (2000) *EMP82-83,* 399-428.

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Figure 1: Single frame from a digital security camera located near Biggar, SK that recorded a portion of the fireball from a distance of ~160 km. This image is from near the end of this location's recorded motion (where the cloud deck covered the last part of the fireball's trajectory and the early portion was above the field of view). The bright fragmentation events produced blooming sufficient to wash out much of the field of view, but the white arrows indicate positions along the trajectory of these bright events that are evident through continued emission presumed due to an afterglow caused by dust thermal emission and meteoric metal emission lines [5].

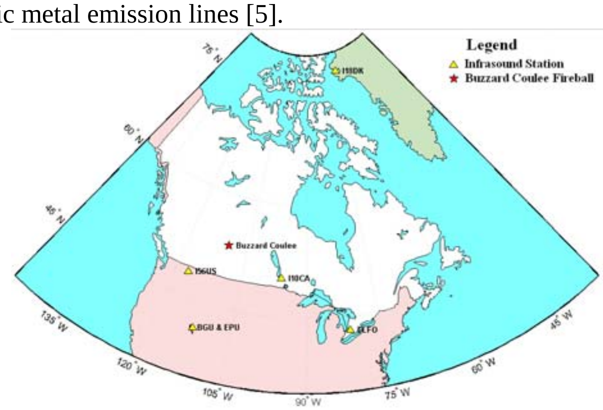

Figure 2: Locations of the six nearest infrasound stations that recorded the Buzzard Coulee fireball. Signal characteristics are strongly directionally dependent due to wind-influenced propagation effects.

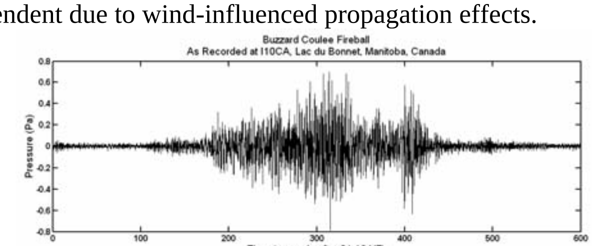

Figure 3: Infrasound record from I10CA located at Lac du Bonnet, Manitoba. This strong signal of >200 seconds duration records multiple arrivals and a very strong stratospheric arrival.