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ANALYSIS OF THE AIRBURST PHENOMENON FROM AN AEROTHERMODYNAMIC POINT OF VIEW: THE CASE OF CHELYABINSK.

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ABSTRACT

Lots of meteoroids entering the Earth's atmosphere disintegrate and cause an airburst before reaching the ground: the meteoroid breaks up into tiny fragments, which are quickly slowed down, an intense light is emitted and a blast wave propagates towards the ground. Several physical phenomena involved in this process have been investigated: interactions between fragments after breakup and their influence on heat release into the atmosphere, as well. The radiative heat fluxes, of prime importance for massive objects at high speed, are estimated. The main aspect of an airburst is the creation of a violent blast wave at low altitude, which can cause serious ground damage. This paper focuses on the blast wave initiation and its aerothermodynamic causes.

The propagation of a blast wave from a given source towards the ground can already be well reproduced by numerical methods (Boslough and Crawford, 2008). However, neither the exact nature of the involved wave nor the exact distribution of energy released in the atmosphere have been clearly identified: they are just inferred. Indeed, two kinds of shock waves could be involved in an airburst: firstly, a bow shock wave forms around the object crossing the atmosphere at hypersonic velocity. Secondly, the blast wave generated by the release of a very important amount of energy in a reduced space. This is the same kind of process as for a bomb, although in the present case, the cause is not related to a chemical explosion but to a sudden and massive dislocation of the object followed by strong heating of the resulting fragments and their air environment. Based on an aerothermodynamic approach,

this work focuses on identifying which of these two shock waves propagates down to the ground and actually causes damage. In the literature, it is often assumed that the shock wave perceived at ground is the supersonic shock wave issued from the hypersonic wake. In this paper, taking the example of the Chelyabinsk event, this view is questioned after showing that the stagnation pressure at the head of the object is not high enough to cause damage on the ground according to analytical approaches. Furthermore, a RANS (Reynolds Average Navier-Stokes) simulation assuming a high temperature chemical equilibrium physical model has been conducted using the code CEDRE developed at the ONERA in order to investigate the expansion of the bow shock wave after the destruction of the object. The influence of different atmospheric models is discussed and the results of CFD simulations are compared to analytical calculations. The paper sheds light on the process of formation and propagation of shock waves and discusses issues relative to ground damage. It also explores the possibility of an airburst in the case of the atmospherical entry of “2015 PDC”, keeping in mind that this asteroid is larger than those that have undergone airbursts so far.