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Towards an engineering model for the entry of meteoroids

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Abstract

This paper introduces the session 'Meteor observations, determination of their properties and link to meteorites' and describes the need for an engineering model of the entry of a meteoroid into Earth's atmosphere.

1. Introduction

In November 2008, the Ministerial Council of the European Space Agency has approved a new optional ESA programme, the Space Situational Awareness preparatory programme. Besides dealing with space debris and space weather, it also contains a near-Earth object segment, henceforth called SSA-NEO. The top-level task of this segment is to track and characterise potentially threatening near-Earth objects, so called NEOs. It is supposed to provide information on how close these objects come to Earth and provide warnings in case of an imminent impact.

2. The need for an engineering model

One of the lower level tasks of SSA-NEO is to assess the effects and consequences of an NEO as it enters the Earth's atmosphere, and also to estimate the damage it would do when reaching the ground. Before the Carancas impact in Peru in 2007, the experts thought that objects larger than ~30-40 m in size would explode in the atmosphere and not reach the ground. This event, however, which created an impact crater of about 14 m diameter, was estimated to be only ~1 m in diameter. Even smaller objects may still be important for the SSA-NEO system. An object as small as a few tens of centimetres could still create a fireball large enough to be mistaken for a missile attack. The fireball may distract pilots and endanger airplane flights. Thus understanding the effects of objects in the decimetre-to-meter size range is still important for SSA-NEO.

Several authors have developed models to describe the path of a meteoroid in the atmosphere using different observational data to constrain their models (light emission, deceleration) and using slightly different physical assumptions or simplifictions (fracturing, different types of ablation, thermal properties). Typically, depending on what physical phenomenon one wants to describe, a different model may have to be used.

For the purpose of the previously described SSA-NEO segment, an "engineering model" to describe a meteoroid's entry into the Earth's atmosphere is needed. While this model does not need to be extremely accurate in all the results, it should allow a forward modelling of all the expected effects on an entering meteoroid. The current scientific models may not be so useful for this purpose.

3. Requirements

The engineering model should allow the modelling of all relevant effects of an incoming meteoroid. The initial parameters for the object are at least:

(a) the total mass/size of the object;
(b) material properties;
(c) velocity and atmospheric entry angle;
(d) time and starting position in space.

The following parameters should – at least to a first order – be computed:

(a) trajectory in the atmosphere;
(b) change of mass versus time
(c) light emission as a function of wavelength versus time
(d) possible other electromagnetic emissions or effects (microwaves, ULF/VLF)
(e) possible fragmentation;
(f) expected pressure or shock waves, resulting in infrasound and/or seismic signatures;
(g) Height of possible explosion and resulting fragment distribution;
(h) Mass and velocity of fragment(s) reaching the ground, be it of the main body or the fragments of an in-air explosion;

(i) For hypervelocity impacts, expected crater size.

In addition, the model should

(j) estimate error bars or ranges for the effects;
(k) have a fast turnaround time, i.e. not take hours of computation time.

4. The way forward

The way forward to develop such a model could be:

1. Compare existing models and identify possible overlaps or combination possibilities, discuss future collaborations. It is expected that in the beginning this would focus on points (a), (b), (c), (e), (g), (h) of the above list.
2. Define what is needed to add information on (d) and (f)
3. Merge this list with requirements coming from other papers at this session

A first discussion on these points should happen during this session. Depending on the result, it could be envisaged to propose an ISSI working group to develop this topic further.