# OPERA: A tool for lifetime prediction based on orbit determination from TLE data

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## ABSTRACT

Objects in Low-Earth Orbits (LEO) and Highly Elliptical Orbits (HEO) are subject to decay and re-entry into the atmosphere due to the drag force. While being this process the best solution to avoid the proliferation of debris in space and ensure the future sustainability of safe space operations, it implies a significant threat. This paper will concentrate on the prediction of the in-orbit lifetime of an space object based on publicly available TLE data.

Unfortunately the lifetime of an object in space is remarkably difficult to predict. This is mainly due to the dependence of the atmospheric drag on a number of uncertain elements such as the density profile and its dependence on the solar activity, the atmospheric conditions, the area-to-mass of the object (which is very difficult to evaluate), its uncontrolled attitude, etc.

In this paper we will present a method for the prediction of this lifetime based on publicly available Two-Line Elements (TLEs) from the American USSTRATCOM's Joint Space Operations Center (JSpOC). TLEs constitute an excellent source to access routinely orbital information for thousands of objects. However, it is a known issue that the reduced and unpredictable accuracy of the TLEs leads to imprecise and unreliable results, if used as such.

Additionally, the implementation of the method on a CNES's Java-based tool will be presented. This tool (OPERA) is executed routinely at CNES to predict the orbital lifetime of a whole catalogue of objects. It uses CNES's STELA (Semi-analytic Tool for End of Life Analysis) as a library for efficient long-term orbit propagation (based on semi-analytical theory) and re-entry date prediction for a given orbit.

For this, several steps have been performed:

1. Filtering of outlier data among the input TLE datasets.
2. Detection of manoeuvring objects (for which the prediction is not performed). Both in-plane and out-of-plane manoeuvres are detected.
3. Preliminary estimation of objects area-to-mass ratio (to be a-priori values for successive final estimation process), based on an innovative method which uses the contribution of conservative and non-conservative forces to the partial derivatives of the orbital parameters versus time.

4. Final estimation of the objects' orbit (initial state vector and area-to-mass ratio for drag and solar radiation pressure) based on a weighted least-squares algorithm having the TLE states as input pseudo-observations. This orbit determination is implemented in equinoctial parameters (set used within STELA) to better control the significance given to each one (as the argument of latitude, for instance) via their a-priori covariance and/or weight matrixes.
5. Prediction of the orbital lifetime for each object by propagation of the estimated orbit (when the object reaches a certain configurable altitude).

This paper describes the algorithms implemented for outliers removal, manoeuvre detection, preliminary area-to-mass ratio estimation and final orbit determination based on the TLE datasets for both LEO and HEO objects. Additionally, the accuracy (estimation error) of the results obtained for known past re-entries will be presented depending on the length of the dataset and the proximity to the final re-entry date.