EARLY WARNING SYSTEM FOR SPACE DEBRIS EARTH IMPACT RESPONSE:

EXECUTIVE SUMMARY

PR00016/D06

I HOLBROUGH, J BECK

Belstead Research Ltd.
387 Sandyhurst Lane
Ashford
UK
TN25 4PF

+44 1233 335054
info@belstead.com

Authorisation
Author: I Holbrough
Reviewer: J Beck
Issue: 1
Date: 28th September 2015

EXECUTIVE SUMMARY

A proof of concept system to predict and track periods when a region of interest is at risk of impact from a re-entering piece of space debris has been constructed. The Time Risk Framework (TRF) uses a number of novel techniques to identify and track periods during which there is an on-ground risk of impact over the last week of a satellite's orbit decay.

As concerns over space debris increase, future missions will be required to dispose of spacecraft and upper stages post-mission. For spacecraft operating at altitudes below 1400km this is most efficiently achieved by the destructive re-entry of the vehicle into the Earth's atmosphere. However, it is well known that these vehicles are not completely destroyed in re-entry, and therefore, there is a risk of casualties on the ground.

Although the prediction of re-entry timing is notoriously difficult, the prediction of when an entering object could impact the surface, within a given zone of interest, is much more certain. By utilising the state-of-the-art destructive re-entry capability existent at BRL, this prediction can be improved, and a surface impact risk level for dangerous objects can be provided. From this, an operational early warning system to place emergency services on standby to respond to potential risks could be constructed.

TRF uses a multidimensional shooting method to construct the initial state vector for a 3DoF aerodynamic propagator. This propagator generates a trajectory through a set of TLE observations, and the shooting method is used to minimise the error between the trajectory and TLEs. The optimised trajectory is then used as the basis for a search of windows during which a region of interest is at risk of impact. Finally, variational data assimilation techniques are used to drive the acquisition of new observations into the catalogue of TLEs. The result is a system which identifies and tracks a set of periods during which there is a risk of injury as a result of re-entering space debris.

In addition to development of the necessary prototype software, its performance has been benchmarked against two historic re-entry events, GOCE in November 2013 and Progress-M 27M in May 2015. Both datasets considered comprise more than 50 TLEs covering the last 10 days of the orbit's decay. TRF has been found to identify specific periods when a region of interest, in this case the mainland UK (8˚W, 59˚N / 2˚E, 50˚N), is at risk of impact, and to track the variation of these time windows as the orbit of the satellite decays.

As a result of this work it has been possible to show that the necessary pre-requisites of such a system are met, specifically that it is possible to:

- Generate a reasonable predicted trajectory for the final days of a satellite re-entry from a set of satellite observations using a 3DoF aerodynamic propagator.
- Extract from this predicted trajectory a set of periods or windows when the region of interest is at risk of impact.
- Assimilate additional observation data points as they become available into the catalogue of observations in a statistically valid manner.
- Track the evolution of the set of risk windows over the assimilation of successive observations, and confirm that they are stable.