Weather Radar Observations of Deorbiting Space Debris

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ABSTRACT

Weather radar imagery is an effective and accurate means of detecting orbital debris falls. The U.S. operates the NEXRAD nationwide weather radar network through NOAA. NEXRAD maintains continuous coverage of the contiguous United States and other sites, and to date at least seven de-orbit events clearly appear in NEXRAD imagery. These include the following de-orbit events: COSMOS 1484 on 28 Jan 2013, Soyuz SL-4 on 23 Dec 2015, COSMOS 2495 on 03 Sep 2014, Iridium on 11 Oct 2018, Long March 7 booster on 28 Jul 2016, Molniya 3-51 on 19 Dec 2016, and the well-known Delta II stage de-orbit 22 Jan 1997. The 1997 event produced weather radar signatures arising from the entire breakup event of the rocket stage, ranging from low-mass objects which separated early in the breakup sequence to high ballistic coefficient objects such as rocket motors which appear towards the end. Weather radar imagery shows falling objects from near Atchison, KS all the way to the vicinity of San Antonio, TX – a distance of over 1,100 km. Falling objects are resolved in terms of appearance time, location, and altitude and a detailed picture of the breakup, distribution, and landing of a wide range of fragments can be constructed.

Weather radar is also effective at locating meteorite falls, and approximately three dozen have been identified in NEXRAD imagery since 1997. Meteorite falls are readily differentiated from orbital debris falls, in that the much higher velocity of meteoroids results in relatively small strewn fields on the order of 10s of km in length instead of >1000 km for space debris. Eyewitnesses also report that space debris infall is a relatively slow process lasting tens of seconds or even minutes, as opposed to the typical 3-10s optically visible duration of a meteorite fall. The author has composed a dark flight model (named Jörmundandr) for accurate calculation of meteorite strewn fields from weather radar data, but has found that the model is of insufficient fidelity to accurately model space debris. While the size, mass, and drag coefficient of meteorites are well constrained and can even be calculated from the weather radar data, these parameters are difficult to constrain for debris. Space debris is composed of a wide range of materials and much of it retains complex shapes after aerodynamic ablation. While this wide range of materials and shapes result in, typically, far greater radar reflectivity than meteorites and thus enhanced detectability, calculating the fall sites of individual pieces results in significant error ellipses. More advanced models than Jörmundandr are needed for accurate strewn field calculation (and fall site calculation for individual objects) of debris. Such a model would be helpful in locating newly-fallen debris, but are not necessary to provide accurate and timely warnings of falling debris for commercial aircraft and sites on the ground.

The author will present radar imagery from the events described here, compare aspects of the data against meteorite falls, and discuss aspects of establishing an aviation+ground warning system for falling debris based in part upon NEXRAD weather radar data.