RAPID RECOVERY OF METEORITES USING WEATHER RADAR: STATUS, STATISTICS, AND FUTURE UPGRADES. M.D. Fries[1], [1]NASA Astromaterials Acquisition and Curation Office, Johnson Space Center, Houston, TX 77058.

Introduction: Weather radars have proven to be a valuable tool for detection, rapid recovery, and analysis of meteorite falls and fall statistics [e.g. 1-3]. The U.S. operates a nationwide weather radar network (NEXRAD) which will be discussed here, but it is important to acknowledge that weather radars operate worldwide and efforts are underway to utilize this rich resource [4]. By the author's count, since the NEXRAD system came online in the late 1990s it has detected 34 recovered meteorite falls and another 34 unrecovered probable falls. Weather radars are powerful tools because they directly detect meteorites falling after the end of their luminous flight, known as the "dark flight" period. This allows rapid recovery through detection and modeling of fall locations down to as little as tens of meters. They are also the only tool that analyzes meteorites that survive their parent fireball, before many or all of them are lost to terrain. This allows direct measurement of meteorite mass, particle size distribution, and with additional work should allow calculation of pre-atmospheric mass and a measure of whole-body strength.

Rapid Recovery: Freshly fallen meteorites are scientifically valuable in that they retain, as best as is possible, a minimally altered state suitable for high fidelity scientific analysis. Weather radar facilitates rapid recovery. At present, social media and other internet-based resources allow detection of meteorite falls within hours of each event. Given the current state of computing power and machine learning and other analyses [5-7] it should be possible to improve this by data-mining the NEXRAD data stream for near-real-time meteorite detection.

Fall Analysis: Weather radar is unique in that it can make measurements on falling meteorites in the period after luminous flight but before they reach the ground. It is possible to calculate the mass of meteorites seen in a given radar pixel from the altitude and time of a given image pixel, as long as the altitude and time of the fireball terminus is known [8]. The number of meteorites present in a given image pixel can also be estimated using the radar reflection strength. For falls where multiple radar detections are made, the mass and number of meteorites can be assembled into a particle size distribution (PSD). It should be possible to use the PSD to estimate whole-body strength of the parent meteoroid, which is an important parameter for any future efforts to divert or destroy hazardous asteroid/meteoroids. It should also be possible to estimate the pre-atmospheric mass as an integration of the PSD curve.

Statistics: We now have 68 meteorite falls and possible falls to work with over 27 years of data collection by the NEXRAD network.. We can investigate these events in a statistical fashion, addressing questions such as whether any pattern exists in fall frequency or whether patterns are visible by month. Logic indicates that the distribution of falls by month should be constant but variations may reveal detection trends due to other possible factors such as observer reporting frequency or seasonal weather effects.

Future Upgrades: The primary route for upgrades to the current process is improvements in software. At present, the author uses the Jörmungandr [9] dark flight model which works well but is notoriously slow. Rewriting this software from MS Excel into Python is underway. Additional software is needed to automate calculation of PSDs. It should also be possible to perform automated near-real time searches of NEXRAD data for signatures of meteorite falls, generating alerts when a meteorite or space debris fall occurs. A data-fusion approach to fall analysis is also possible, merging publicly available datasets into a single platform to speed the discovery and analysis of falls. Data could be accumulated from NEXRAD, the Geostationary Lightning Mapper (GLM) sensors which have proven to be efficient bolide detectors [10], seismometer and infrasound data, eyewitness reports from sources such as the American Meteor Society [11], and others as new data sources evolve.

References: [1] Fries, M. and Fries, J., 2010. MAPS, 45(9), pp.1476-1487. [2] Brown, P. et al., 2011. MAPS, 46(3), pp.339-363. [3] Jenniskens, P., et al., 2012. Science, 338(6114), pp.1583-1587. [4] Devillepoix, H.A.R., et al., 2020.. PSS, 191, p.105036. [5] Hankey, M., et al 2017.. PSS, 143, pp.199-202. [6] Citron, R.I., et al., 2021. MAPS, 56(6), pp.1073-1085. [7] Smeresky, B., et al 2021. MAPS, 56(8), pp.1585-1596. [8] Fries, M. et al, 2017, July. In 80th MetSoc (Vol. 80, p. 6251).[9] Fries, M.D., 2023, March. In *54th LPSC*. [10] Jenniskens, P., et al, 2018. *MAPS*, *53*(12), pp.2445-2469. [11] https://amsmeteors.org/fireballs/fireball-report/