

Title: Radar Measurements of the LEO Orbital Debris Environment

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Author Bios:

Chris Blackwell serves as the contractor task lead for the NASA Orbital Debris Program Office (ODPO) radar measurements group. Mr. Blackwell has earned a BS in Physics from North Carolina State University and an MS in Physics from the University of Alabama in Huntsville. Before joining the NASA ODPO contractor team in 2016 Mr. Blackwell supported the Missile Defense Agency in Huntsville, AL as a contractor performing radar systems analysis.

Timothy F. Kennedy, timothy.f.kennedy@nasa.gov, received the B.S. (summa cum laude), M.S., and Ph.D. degrees in electrical engineering from the University of Houston, Houston, TX in 2001, 2003, and 2006 respectively. Prior to joining NASA in 2005, he was with the geophysics group at Schlumberger (SPC), where he conducted work on inverse problems, layered media, and software development. Dr. Kennedy started his career in the Electromagnetics Systems Branch and later the Wireless and Communication Systems Branch at the NASA Johnson Space Center working in the areas of computational electromagnetics modeling and software development; antenna systems design, development, and testing in support of the Orion and ISS programs; and data science and RFID tracking technologies for the Advanced Exploration Systems (AES) and ISS programs. He is currently the radar lead for the Orbital Debris Program Office. Dr. Kennedy has 16 issued patents, and more than 20 conference and journal publications.

Motivation and Significance

Access to space and the preservation of the near-Earth space environment is of critical significance. Increased interest in issues surrounding space traffic management and the continued assessment and discussion of orbital debris at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) illustrates the significance of the topic of orbital debris.

There are currently over 20,000 tracked objects in the publicly available satellite catalog on Space-Track.org. The catalog is maintained by the US Air Force Space Command using a network of optical and radar ground-based sensors and is believed to be complete for a characteristic size of 10 cm or larger in low Earth orbit (LEO). Based on the work of the NASA Orbital Debris Program Office (ODPO) over approximately the past 40 years it is understood that the small debris population (< 10 cm) increases by orders of magnitude as characteristic size decreases. With population estimates ranging from 500,000 to 1,000,000 small debris objects (> 5 mm) in orbit, it is currently not practical to track and maintain precision orbits on every object. Instead the NASA ODPO uses powerful ground-based radars to sample the low Earth Orbit (LEO) environment and assign approximate orbits to each detection. This poses an interesting signal processing challenge as we are trying to detect the smallest objects possible on the edge of the radar's sensitivity. For approximately the last 30 years, NASA ODPO has partnered with the Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL) to utilize the Haystack Ultra-wideband Satellite Imaging Radar (HUSIR - formerly the Long-Range Imaging Radar or simply Haystack) and the Haystack Auxiliary (HAX) radar to collect orbital debris radar data.

Additionally, the ODPO collaborates with the NASA Jet Propulsion Laboratory (JPL) to use the Goldstone Solar System Radar. The orbital debris detections from these radars serve as inputs for statistical risk models used by the human spaceflight and satellite communities to assess risk to spacecraft posed by orbital debris.

In this paper, we will describe the history of orbital debris radar measurements conducted by NASA, provide an overview of current radar measurements techniques and facilities, discuss the signal processing software used for orbital debris measurements and the inference of debris size and orbital parameters from these measurements, and discuss how orbital debris radar measurements are validated for use in models that are used throughout the aerospace industry.

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 - a. Count rate, flux, false alarm rate
 - b. Sodium Potassium Population
 - c. Comparison with the NASA Orbital Debris Engineering Model (ORDEM)
5. Environment Characterization
6. Conclusion

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