GROUND RADAR DETECTION OF METEOROIDS IN SPACE

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The North American Air Defense Command (NORAD) has the responsibility of detecting and tracking artificial satellites in Earth orbit. Objects detected with a velocity in excess of the escape velocity of Earth are normally disregarded by the ground radar since they are obviously not orbiting satellites. During a special test conducted by NORAD for NASA to lower the detection threshold for small satellites, part of the radar software was modified, resulting in acquisition of what appears to be important new meteoroid data. The purpose of this paper is to describe the special test and give a preliminary analysis of the meteoroid data.

The test was motivated by concern that there may be a large number of satellite fragments in Earth orbit which are too small to be routinely detected by radar, yet large enough to do significant damage to a spacecraft if a collision should occur (see Kessler, and Cour-Palais, 1978). The test was performed by NORAD's Perimeter Acquisition Radar Attack Characterization System (PARCS). The PARCS radar, located at Concrete, N. Dakota, is a large, planar face, phased radar, operating at a nominal 430 megahertz (wavelength of .7m), boresighted 8° east of True North at a 25° elevation angle. In the satellite detection mode of operation it executes a raster scan of the region bounded roughly by the azimuth limits of 55° each side of the boresight azimuth and 1.8° to 45° in elevation. In addition, it has a high elevation detection "fence" of radar energy with peak elevation at approximately 82° and minimum elevation at approximately 56°. For this test, once detected, an object could be tracked to 70° from boresight so long as it was above 1.8° elevation (or 185 km altitude for objects near the site), within the range spread of 250 to 3300 km, and with signal strength above the signal-to-noise threshold (∿3 dB S/N). These characteristics are somewhat different than the normal system operational parameters, and prevented the system from performing its normal missions during the period of test. The peak radiated power is 14.3 mW while the average is 715 kW.

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The radar produces 120 pulses per second, 45 of which are dedicated to search. Any of the remaining 75 pulses not required for tracking are added to the search function to enhance the probability of detection. The probability of detection of a given size object at a given range is classified. However, because an object typically has several opportunities to be detected during the time it is within the detection region, the probability of detection is high. The time required to scan the entire search region varies as a function of the number of pulses available but is always less than 1 minute.

Changes from the tactical software included reducing the signal to noise threshold, elimination of a less than 0.001 m^2 restriction on radar cross sections and elimination of a greater than escape velocity restriction on satellite velocity. However, since the prospect of detecting meteoroids was not considered at the time of these modifications, a filter which eliminated objects whose range rate was greater than 10 km/sec remained in the test software. Thus, data on objects whose velocity component along the radar line of sight was greater than 10 km/sec were not processed or saved. Consequently, objects detected with velocities in excess of escape velocity are statistically biased toward lower velocities.

The test consisted of 8.4 hours of observation during the period between August 21 and 23, 1978. During this interval, over 6000 objects were detected and tracked. Of these, 37 were determined to have velocities greater than escape velocity. Again, because meteoroid detection was not planned, total velocity information was not calculated, and it is possible that some of these 37 are actually orbiting satellites, with large uncertainties in the measured velocity. Six have radar cross sections greater than .1 m^2, while the remaining 31 have cross sections less than .01 m^2. These six have a mass and altitude distribution that is similar to orbiting satellites, while these distributions for the smaller group are markedly different than the orbiting population, but similar to that for meteoroids. Thus, it is probable that most of these larger objects are orbiting satellites. Further reduction of the data is planned to resolve this possibility, but for the present, these six objects will be treated separately.

The following figure gives the flux of these two observed groups. For this figure, radar cross sections of less than .0132 m^2 were adjusted for Rayleigh scattering, and the area of the objects were assumed to be equal to this adjusted radar cross section. Mass was found by assuming a density of 2 gm/cm^3. The area-time product for this experiment is approximately 1×10^4 km^2-yr (within a factor of 2), including Earth shielding and the velocity selection effect mentioned previously.

Planned further analysis includes determining the heliocentric orbits. However, in any future test with this radar system, all velocity filters would be removed to allow for complete detection of meteoroids. In addition, the data reduction could be planned in such

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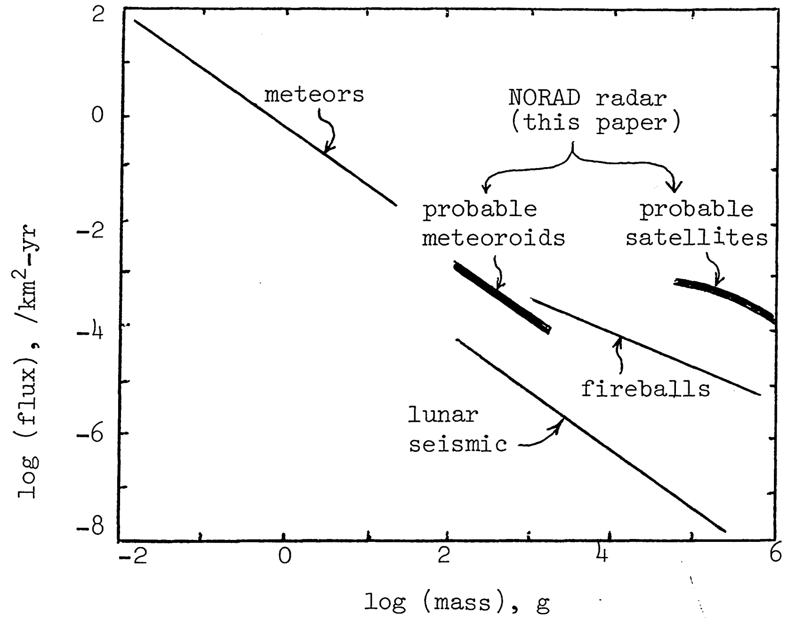
a manner to give immediate information on velocity, uncertainty in velocity, and the heliocentric orbit.



Observed Flux by NORAD Radar of Objects Greater than Earth Escape Velocity, Compared to other Measurements as reported by Duennebier, et.al., 1975.

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