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Introduction: The orbit of the near-Earth asteroid (101955) Bennu is well-constrained from ground-based observations. The wealth of ground-based optical and radar data collected since the Bennu discovery in 1999 over about 15 years allowed an estimate of the semimajor axis accurate to within 20 m. These data also allowed a 200-σ detection of the Yarkovsky effect acting on Bennu as well as deterministic ephemeris predictions through the Earth close approach in 2135 [1].

OSIRIS-REx data: The OSIRIS-REx mission to Bennu [2] has provided data that further constrain the asteroid's trajectory to an unprecedented level. On 2018-08-17 Bennu was first detected with OSIRIS-REx's PolyCam [3], and optical navigation measurements [4] during the Approach phase constrained the location of Bennu in the OSIRIS-REx plane of sky to within a few kilometers [5]. Upon arrival, the OSIRIS-REx spacecraft started operating in Bennu's proximity. During Preliminary Survey, Orbital A, Detailed Survey, and Orbital B radio ranging data [6] to OSIRIS-REx constrained the distance between Earth and Bennu to within a few meters from December 2018 to August 2019.

High-fidelity trajectory modeling: While these data greatly improve the knowledge of Bennu's trajectory, they also require high-fidelity modeling of the perturbations affecting Bennu's motion. For example, the fit to OSIRIS-REx ranging data is sensitive to short-term perturbations caused by the Yarkovsky effect, which depends on Bennu's thermal inertia. Therefore, accurately tracking the motion of Bennu provides an indirect, but completely independent, estimate of Bennu's thermal inertia that can be compared to OSIRIS-REx's direct thermal measurements [7]. Even errors of few degrees in the Bennu rotation pole cause errors in the Yarkovsky modeling that are visible in the fit to the ranging data. Moreover, radiation effects such as the Poynting-Robertson drag [8], so far only considered for interplanetary dust dynamics, now become a consideration for modeling the trajectory of a 500-m asteroid.

Hazard assessment: Bennu is a potentially hazardous asteroid and, based only on ground-based data, there is about 0.04% probability of an Earth impact between 2175 and 2196 [1]. We will show how the OSIRIS-REx mission data through the Orbital B phase change the statistical assessment of the possibility that Bennu reaches the Earth late in the 22nd century. Given the formal precision achieved on the Bennu orbit estimate, systematic modeling errors become a consideration. Special care must be taken in assessing the errors caused by the uncertain masses of perturbers as well as the path delay calibration for the OSIRIS-REx spacecraft antennas. While many potential impacts previously detected can now be ruled out, we identify those that might persist and refine the estimated impact probability.

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