MASS AND GRAVITY FIELD ESTIMATION OF (101955) BENNU FROM OSIRIS-REX OBSERVATIONS. J. W. McMahon[1] A. S. French[1], D. J. Scheeres[1], D. N. Brack[1], S. R. Chesley[2], D. Farnocchia[2], Y. Takahashi[2], J. Leonard[3], J. Geeraert[3], B. Page[3], P. Antreasian[3], K. Getzandanner[4], D. Rowlands[4], E. Mazarico[4], J. Small[4], M. Moreau[4], M. C. Nolan[5], D. S. Lauretta[5], and the OSIRIS-REx Team, [1]Smead Department of Aerospace Engineering Sciences, The University of Colorado Boulder (jay.mcmahon@colorado.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, [3]KinetX, Simi Valley, California, [4]NASA Goddard Space Flight Center, [5]Lunar and Planetary Laboratory, University of Arizona.

Introduction: The OSIRIS-REx Radio Science Working Group used radiometric tracking data [Doppler, range, and delta-differential one-way range (DDOR)] obtained between the OSIRIS-REx spacecraft and the DSN, as well as landmark tracking data in optical images taken by the on-board cameras to estimate the mass and gravity field of Bennu. Data for this solution were acquired primarily during three mission phases: Approach, Preliminary Survey, and Orbital A.

The OSIRIS-REx spacecraft began the Approach phase towards asteroid Bennu on August 17th, 2018. During Approach, the spacecraft performed six maneuvers to decelerate the spacecraft with respect to Bennu and place it at the Preliminary Survey starting location on December 3rd, 2018. Preliminary Survey consisted of five flybys—three over the north pole, one over the equator, and one over the south pole—and two transition legs. Each flyby started approximately 18.5 km from Bennu, took 48 hours to complete, and achieved a closest approach of 7.5 km at the 24 hour mark. The polar flybys were along the terminator and the equatorial flyby was on the sunlit side. All flyby and transition arcs were joined by maneuvers that varied between 20 and 40 cm/s. On December 31, 2018, the spacecraft entered into a 1.5 x 2.0 km orbit around Bennu.

Methodology: The Radio Science Working Group orbit determination solutions were computed using JPL's Mission Analysis, Operations and Navigation Toolkit Environment (MONTE) and Goddard's GEODYN tool. Details of the methodology are found in [1]. Analogous solutions computed by the Flight Dynamics Team have shown consistent results.

The dynamic models for our fits included Bennu's gravity field up to second degree and order, solar radiation pressure, stochastic accelerations, and third body perturbations from the Sun and planets. Bennu's shape, spin state, and landmarks were provided by the Altimetry Working Group [2].

Images taken by spacecraft cameras (PolyCam, MapCam, NavCam1) were used to generate center-finding and landmark optical navigation data. These data, along with X-band two-way Doppler, two-way Range, and DDOR from the Deep Space Network (DSN), were used to determine both the spacecraft trajectory and Bennu's ephemeris.

Two-way Doppler and two-way Range were weighted per-pass and per antenna. Per-pass range biases were estimated. Optical data was weighted by phase.

Non-gravitational perturbations to the spacecraft trajectory were characterized prior to the start of Preliminary Survey in order to minimize aliasing between so- lar pressure, stochastic accelerations, and GM. Area scale factors for each of the sunward facing plates were estimated on approach to account for solar pressure and thermal radiation mis-modeling. The plate areas were then held fixed during Preliminary Survey and a single solar pressure scale factor was estimated. Stochastic accelerations were estimated in 12-hour batches with an a priori uncertainty of $5x10^{-13}$ km/s^2. Due to the regular cadence of the flyby/maneuver cycle, the stochastic accelerations were correlated exponentially with a 3-day time constant after M1P to prevent interplay with the GM and the maneuvers.

Results: The final reconstructed uncertainty for the spacecraft's Bennu-relative state during Preliminary Survey averaged approximately 5 meters in position and 0.2 mm/s in velocity for each axis, 3-sigma. Solutions were generated for various data weights, stochastic un-certainties, batch lengths, and correlation times to show consistency.

As of the date of submission of this abstract (early Orbital A), the result of these fits shows an estimate of Bennu's GM of 4.89 +/- 0.03 m^3/s^2. This will be updated with Orbital A data before presentation. Initial estimates of the center-of-mass to center-of-figure offset and the second-degree gravity terms will also be presented.

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