THE SENSITIVITY OF (99942) APOPHIS' NECK TO RESURFACING DURING THE 2029 EARTH FLYBY. Y. Kim[1], M. Hirabayashi[1], R. P. Binzel[2], and M. Brozović[3], [1]Auburn University, Department of Aerospace Engineering, Auburn, AL 36849 (yzk0056@auburn.edu), [2]Massachusetts Institute of Technology, Cambridge, MA 02139, [3]NASA/JPL Caltech, Pasadena, Ca 99190.

Introduction: Granular alterations derived by solar wind irradiation [1] and micro-meteorite bombardments [2], which are known as space weathering processes, cause optical variations in an asteroid's surface. This process results in the spectra mismatch between the ordinary chondrite meteorites (OCs), the most common type of meteorites found to date, and S-type asteroids as the source of the OCs [3]. While most main belt asteroids are affected by space weathering, a high fraction (~25%) of near-Earth asteroids (NEAs) appear unweathered surfaces [4], indicating that a hitherto unknown resurfacing process acts on NEAs. Previous studies proposed that the resurfacing mechanism is possibly associated with close planetary encounters [4 – 7]. However, the detailed mechanism of resurfacing is still not well understood. If tidal effect may contribute to resurfacing on asteroids – in the form of either shape modification or landslides, which may expose unweathered surface materials – expected to have the closest Earth flyby within 6 Earth radii on April 13, 2029, Apophis is considered to be a key opportunity for directly observing this unknown geophysical process. This study aims to numerically quantify the tidal effect acting on Apophis and investigate the observability of any resurfacing features during its 2029 Earth flyby.

Methodology: We first develop a dynamic model [8] for computing the surface slope evolution of Apophis during the flyby with the radar-derived shape model [9]. Second, we employ a finite-element model (FEM) approach [10] to estimate its structurally failed regions based on the structural strength.

Dynamic model. This model computes the surface slope evolution of Apophis by simulating its orbital and spin evolution. The surface slope describes how the surface element is tilted on the direction of its total force – combined with the gravity, the tidal force from the Earth, and the rotation-driven force on each facet. Using the surface slope evolution, we predict unstable regions where surface regolith may be incipiently set in motion.

FEM approach. This model estimates the structural failure conditions on Apophis by the tidal effect. We use the ANSYS FEM solver and obtain elastic-plastic solutions by applying tidally induced loadings acting on each node in the FEM mesh. The FEM analysis predicts how the surface and sub-surface regions that may have low cohesion [11, 12] are structurally failed, leading to additional resurfacing.

Results: Our dynamic model estimates that about 1.3% of the entire surface area of Apophis will be unstable to experience landslides, given 35° of the angle of repose [13], during the 2029 Earth flyby. The unstable regions approximately match the structurally failed regions (the yellow areas in Fig. 1) from the FEM approach, explicitly showing that the neck regions would become structurally unstable. The cohesive strength to cause structural failure during the close encounter is estimated to be 0.3 Pa, which is very weak.

Although the resurfacing correlates with Apophis' shape, the used shape model has high uncertainties due to the weak radar signals. Thus, we expect the future radar observation in March 2021 will improve Apophis' shape and spin estimates, allowing us to provide further constraints on resurfacing.

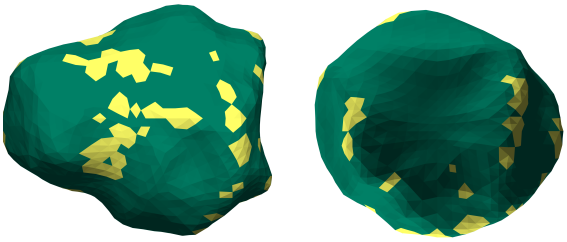

Fig. 1. Apophis' structural failures at the closest approach. The yellow regions describe failed regions where the current stress exceeds the yield condition. The Drucker-Prager yield condition is applied to define the yield condition [14].

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