MRD 150- Yarkovsky Acceleration

Data Product Overview

This data product is responsive to MRD-150 (2.14.1) Measure the Yarkovsky acceleration of Bennu with a SNR ≥400.

This document discusses only the Yarkovsky measurement aspect of MDR-150. Other aspects are covered elsewhere, for example:

- Bennu ephemeris
- Bennu pseudo-ranging measurements
- Bennu planetary encounters and impact hazard analysis

This data product will be in the form of a journal article that describes the key result (i.e., measurement of the Yarkovsky effect) along with the input data and algorithms. **This data product is not a SPOC deliverable.**

Background

The Yarkovsky effect describes a small but significant force caused by sunlight; when small bodies heat up in the Sun, they eventually re-radiate the energy away as heat, which in turn creates a tiny thrust.

The recoil acceleration from the Yarkovsky effect can produce substantial orbital changes over long periods, but its strength is weak and observations have inherently finite accuracy. Tracking data from three sources will constrain the deviation of the asteroid orbit from a gravity only trajectory:

1. Ground-based optical astrometry
2. Ground-based radar astrometry (delay and Doppler)
3. Pseudo-ranging from a DSN tracking station to the asteroid center of mass

The generic approach is to fit all of the available observations, given their stated (or assumed) a priori uncertainties, in a least-squares fit that estimates the initial condition (osculating orbital elements) and relevant nongravitational parameters. The nongravitational parameters ultimately reveal the presence and significance of the Yarkovsky effect.

Inputs

The inputs required to obtain a measurement of the Yarkovsky effect include

- Bennu shape model
- Bennu spin state
- Bennu thermo-physical model

- Bennu pseudo-ranging measurements
- Ground-based optical and radar astrometry, which are obtained from the IAU Minor Planet Center and the JPL Solar System Dynamics websites, respectively.

Data Product Structure and Organization

The Yarkovsky measurement may take multiple forms, depending on the context and relevant level of fidelity. In the simplest presentation the key result is an orbit averaged time rate of change of semi-major axis, i.e., da/dt, along with its formal uncertainty. More detailed descriptions of the Yarkovsky effect may involve modeling or measurement of radial-transverse-normal components of thermal recoil accelerations in order to investigate their observability within the available astrometric data set.

Data Format Descriptions

The Yarkovsky measurement will be described and documented in a peer-reviewed journal article.

Data Product Generation

This product development will be led by Co-I Steve Chesley. He will use preexisting, proprietary codes that exist at the JPL Solar System Dynamics group. His work will be submitted to the OSIRIS-REx science team and peer review journals as a means to check his results.

Data Product Validation

As has been done with various other objects, including Bennu, the Yarkovsky measurement will be checked for internal and external consistency with multiple thermal recoil acceleration models. Among these are

- Comet-like nongravitational acceleration model. Does not require any thermal, spin, or shape information.
- Linearized heat transfer model of a uniform sphere with known thermal inertia and spin state. Does not require knowledge of a shape model.
- Nonlinear, finite element thermal model of specific asteroid shape with known spin state and uniform surface properties.
- Comprehensive thermo-physical model of Bennu based on the results of MRD-156.

The various models serve as independent validation of the overall result and aid interpretation of which modeling aspects are more and less important for high fidelity.