NFT Local Safety Map Algorithm Description Document

Overview

NFT provides layers of Component Level Fault Protection by estimating the time and location of touch on the surface of Bennu. In addition, the time of touch estimate is also used to define a time window where the sampling mechanisms are armed. If time of touch is not detected within this window, a backaway burn will be initiated to ensure spacecraft safety.

This data product supports the Safety Map requirement SM. ALG.12: "SPOC shall generate a site specific gravity input map for each potential sampling site. The site specific scale gravity map will provide a measure of the uncertainty present in the gravity model for each targeted sample site." This safety map algorithm provides a measure of how accurately NFT will be able to predict the time of touch given uncertainties in the gravity field for a specific TAG site. The Bennu gravity field is defined using spherical harmonics. The uncertainty in this model is represented by a covariance matrix estimated by the Flight Dynamics team. To assess the measurement error NFT may experience in estimating the time of touch, the gravity field covariance can be sampled for each candidate TAG site. The sampled uncertainty in gravitation acceleration can be propagated to the surface to produce an estimated time of touch when using a perturbed gravity field. The same operation can be executed using the nominal gravity field. With a perturbed estimate and a nominal estimate for the time of touch, the difference between these two will provide the potential time of touch error when navigating to the candidate site.

The output of this safety map algorithm will result in each candidate TAG site being ranked in terms of how well NFT is expected to perform the time of touch calculation.

Inputs

- Global 75cm or 35 cm Shape Model
- Spherical harmonic gravity model from Radio Science campaign
- Spherical harmonic gravity model covariance from FDS
- TAG site locations to test in ACF frame
- Initial spacecraft C.G. location for propagating down to the TAG site (should use 20 m altitude)
- Configurable spacecraft C.G. to TAGSAM head body vector
- Configurable poor and favorable time of touch thresholds

Outputs

- NFT local safety map

Algorithm

For each candidate site, propagate the state uncertainty caused by the gravity field model from 50 m and 20 m altitude to the surface to evaluate the estimated time of touch error.

1) Set spacecraft C.G to configurable initial state above each TAG site defined as t0
2) Sample nominal gravity field to get nominal gravitational acceleration
3) Sample 3-sigma gravity field to get 3-sigma gravitation acceleration

4) Propagate spacecraft state from t0 until the TAGSAM head touches the surface using the nominal accelerations. Define the time of intersection as t_{TAG_Nom}
5) Propagate the spacecraft state from t0 until the TAGSAM head touches the surface using the 3-sigma accelerations. Define this time of intersection as t_{TAG_3sig}
6) Calculate the difference in intersection times between t_{TAG_Nom} and t_{TAG_3sig}. This represents the time of touch error we could experience when using this TAG site.
7) If the time of touch error is ≥ 3.75 sec (configurable value), mark that TAG site as "poor" for NFT TAG
    a. Note that the NFT time of touch budget allocates 5 sec total for propagation errors. This includes both spherical harmonics representation error and uncertainties. Because this safety map is only assessing uncertainties, a fraction of the total 5 sec should be allocated to this safety map check. Pre-launch analysis has shown that the worst case representation error over the simulated asteroid is 1.25 sec assuming a 20 m propagation. This leaves 3.75 sec for uncertainties.
    b. References for gravity uncertainties and representation error are available from the NFT team.

8) If the time of touch error is ≤ 2 sec (configurable value), mark that TAG site as "favorable" for NFT TAG
9) Any values in-between the limits defined in #7 and #8 above can be graded on a relative scale from poor to favorable.