NEOShield

A Global Approach to Near-Earth Object Impact Threat Mitigation

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1 Abstract

The objective of this work has been to assess the currently known NEO population in terms of orbital parameters and physical knowledge, and provide a prioritized target list for demo-mission designs. In April 2013 when this was performed, six candidates were identified, the first ranked being (190491) 2000 FJ10. These were then passed to IMCCE for orbital evolution calculations and Astrium-DE for mission feasibility studies. All six potential targets would benefit from further earth-based reconnaissance, which is possible for four of them within the next 2 years. We note that selection of a previously characterized NEO would remove several uncertainties in mission planning, but would require targeting a larger asteroid than currently envisaged.

2 Background and Objectives

For NEOShield partners to accurately assess the options for mitigation demonstration missions, suitable potential targets in the known NEO population must be identified. The continued and increasing rate of discovery of NEOs – now at almost 1,000 per year – makes this a moving target (excuse the pun). However, only a minority of these NEOs have well-known orbits with small uncertainties, highlighting the requirement for simple astrometry of faint NEOs for orbital improvement. The rate of characterisation is unfortunately much slower still. Hence there is a far smaller set of NEOs from which to select spacecraft mission targets than one might expect.

The objective of task 5.3b was to take the known NEO population at the time of writing (spring 2013), and select a handful of potential targets based on their orbital elements and physical knowledge. These would then be studied in work packages 5 and 8 to assess potential mission scenarios to these objects.

3 Selection of Potential Mission Targets

3.1 NEO source catalogues

The source for target selection was the updated lists generated by the NEOShield deliverable D5.2 (Fitzsimmons 2012).

3.2 Selection Criteria

The mitigation-relevant factors influencing the choice of target are fully described in NEOShield deliverable D5.1 (Harris & Drube 2013), and only require a brief summary here.

<u>Orbital Parameters</u>
The most important parameters here are the delta-v required to rendezvous with the NEO, the uncertainty in the orbital parameters, and the current position of the NEO in its orbit that dictates the potential mission trajectories. The delta-v and orbital uncertainty is available from the NEO target. The future accessibility is the task of D5.3a and WP8.

<u>Size</u>
As discussed in D5.1, it was decided that objects in the diameter range 100m-300m should be chosen.

<u>Spin</u>
During the NEOShield discussion meeting in April 2013, it was agreed that extremely fast spinning NEOs may cause problems for gravity-tractor demonstrations. Therefore spin periods less than 2 hours should be avoided if

possible. We note that this may cause problems at the smallest diameters considered, due to the observed population of fast rotating NEOs with diameters <150m.

Shape
At the same meeting, it was agree that highly elongated objects should be avoided where possible. For many objects, this is roughly estimated from the lightcurve amplitude at one epoch. Therefore it should be remembered estimates of elongation are often a lower limit.

Composition
The NEO population contains samples of all known spectral classes of asteroid. However it was agreed that the best choice would be selection of targets that represented the most likely impactors on Earth. This would correspond to an S-class or C-class object. Additionally, as the density of S-class asteroids is better characterised through previous space missions (Eros, Itokawa, Gaspra), and would cause less problems with kinetic impactor targeting due to their higher albedo, they would be preferred.

Binarity
It is estimated that ~15% of NEOs are binaries. For this stage of the NEOShield project, it was agreed that known binaries should be avoided. It is important to note that it is impossible to preclude a binary nature for most NEOs based on existing data, and this includes the targets selected below.

3.3 Selection Process

NEOs were prioritised in the following fashion:

Rendezvous Delta-v – As this was the primary orbital parameter, this was used as the initial sorting criterion.

Orbital Uncertainty – only NEOs with well established orbits can be chosen, to ensure accurate planning of a successful rendezvous mission and/or kinetic impactor targeting.

Size – This was used as the primary physical requirement. For some objects the size is accurately known either through radar observations or thermophysical and/or NEATM modelling. For other cases it is inferred through a measured albedo or spectroscopic classification, combined with the observed absolute magnitude.

For the vast majority of NEOs only the absolute magnitudes are known, and these objects are therefore unsuitable due to their highly uncertain diameters.

Spin/Shape/Albedo/Composition – It is important that potential mission targets are as fully characterised as possible. Therefore objects were highly ranked if they had at least two of these properties measured or constrained by previous observations.

Future Observability – This is important for both orbital refinement and Earth-based physical reconnaissance. Most NEOs in the required size range are not easily observable from Earth during the period of the NEOShield project. Therefore a weak selection criterion was that the NEOs should be observable again from Earth before the end of the decade.

4 Selected Targets

The following targets were selected as the best possible within the above constraints, as of 20th April 2013.

1. (190491) 2000 FJ10. This Amor asteroid has a spectrum clearly indicating an S-type composition, probably Sq (Christou et al. 2012). The measured absolute magnitude of H=21.5, coupled with an mean albedo for Sq-type asteroids of 0.29 (Thomas et al. 2011), implies a diameter of D=130m. The rotation period is constrained by observations to be > 2 hours, with a minimum axial ratio of 1.3.

Its next favourable apparition will be in July-August 2014, when its apparent magnitude of V~20 will allow both orbital refinement and further lightcurve studies, with a possibility of spectroscopy should a 4m-8m facility be available.

Finally, we note that Christou et al. identified 2000 FJ10 as a potential science mission target, and presented an analysis of ballistic trajectories for a sample-return mission.

2. (65717) 1993 BX3. This Amor asteroid is listed as having a diameter of approximately 200m by Binzel et al. (2002). However the diameter is uncertain as it is based on the absolute magnitude and an albedo of 0.15, and it is unclear how the albedo was derived. The rotation period has been measured as 20.463 hours with an amplitude of 0.91 magnitudes, implying a minimum axial ratio of 2.3. (Mottola et al. 1995).

Its next favourable apparition will be in September 2015, when its apparent magnitude of V~20 will allow both orbital refinement and further lightcurve studies, with a possibility of spectroscopy should a 4m-8m facility be available.

3. 2001 QC34. This Apollo asteroid has a Q/O spectrum indicative of a fresh silicate surface (Vilas et al. 2008). Coupled with an assumed albedo of 0.21 and a recorded absolute magnitude of H=20.0, this implies an approximate diameter of 290m. The spin rate is unknown.

This NEO will be visible from Earth from August through to October 2013 at an apparent magnitude of V < 20, allowing photometry and astrometry from 1-m to 2-m class telescopes, and spectroscopy from 2m-4m class telescopes. It will also be visible at similar brightnesses from April-June 2014.

4. (162416) 2000 EH26. This Apollo NEO has a directly measured diameter of 141m (Mueller et al. 2011). Combined with its absolute magnitude of H=21.70, this implies an albedo of 0.18 indicative of a probable silicate composition. Radar observations during 2000 allowed a lower limit on the diameter of D<60m to be established, in agreement with the above measurement. The same measurements had a bandwidth either implying a subradar latitude near the rotation axis, or alternatively a rotation period > 1 day if observed near the equator.

There are no suitable apparitions for further Earth-based studies before the end of the decade.

5. (354182) 2002 DU3. This is an Apollo object with a spectral classification of Sq (Binzel et al. 2004a). The measured absolute magnitude of H=20.7, coupled with an mean albedo for Sq-type asteroids of 0.29 (Thomas et al. 2011), implies a diameter of D=180m. The spin rate is unknown.

The current orbital uncertainty is the larges of the targets presented here, with a current 3-sigma sky-plane uncertainty of ∼ 3 arcsec. This is likely to be significantly improved during its next favourable apparition in September-October 2013. Its apparent magnitude of V=19–20 will allow both orbital refinement and further lightcurve studies, with a possibility of spectroscopy should a 4m facility be available.

6. 2001 JV1. This is a PHA with a spectral classification of Sq (Binzel et al. 2004b). The measured absolute magnitude of H=21.4, coupled with an mean albedo for Sq-type asteroids of 0.29 (Thomas et al. 2011), implies a diameter of D=130m. The spin rate is unknown, but the radar detection in 2001 implies a spin rate < 29 hours (Benner 2013).

There are no suitable apparitions for further Earth-based studies before the end of the decade. However the orbital uncertainty is currently small due to the radar detection.

5 Discussion

The above 6 targets represent the best available at present for NEOShield planning. It is hoped that the situation regarding the albedo and probably diameter of (65717) 1993 BX3 will be clarified in the near future, and that further observations of this NEO will be performed in 2015. In total, four of the six NEOs selected in this document are amenable to further Earth-based observations in the next 2 years.

The fact that so few NEOs of the in the required size range of D=100m–300m possess measurements of physical characteristics, even after the Explore NEOS and NEOWISE projects, underlines the importance of continuing reconnaissance.

Finally, we note that the current size requirements precludes the selection of NEOs targeted by approved/flown missions such as (25143) Itokawa and (101955) Bennu, both of which are ∼500m objects. As suggested in NEOShield deliverable D5.1 (Harris & Drube 2013), and similar to the recent ISIS/OSIRIS-

REX proposal by Chesley et al., a mitigation demonstration mission to a previously well-characterised NEO could provide significant advantages in mission planning and cost.

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