THE NEO TOOLKIT: A NEW SET OF ASTRONOMICAL TOOLS FOR THE NEAR-EARTH OBJECTS COMMUNITY

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ABSTRACT

Providing astronomers of the near-Earth Objects (NEO) field with useful tools is one of the long-term goals of ESA's Planetary Defence Office (PDO) and its NEO Coordination Centre (NEOCC[1]).

The new NEO Toolkit, an online browser-based set of free tools newly developed by the PDO and recently released to the public, consists of four specialised and complementary tools that aim to cover many of the observational aspects of NEOs.

1. THE NEO TOOLKIT: COMPONENTS

The NEO Toolkit is currently composed of the following elements:

- The Observation Planning Tool (OPT) provides the users with precise ephemerides and observational data from NEOs to help planning and scheduling observations in the forthcoming nights (see screenshot of the long-term plots produced by the OPT of an actual planning in Figure 1).
- The Sky Chart Display Tool (SCDT) supports the observations by producing a visualisation of the orbits of the NEOs in the sky as observed from any location in the world (see screenshot of a sky chart displaying a few NEOs as produced with the SCDT in Figure 2).
- The Orbit Visualisation Tool (OVT) allows visualising Keplerian and perturbed orbits of one or more asteroids and comets (only Keplerian orbits) simultaneously in a 3D environment (see Figure 3 for a sample depiction of the Keplerian and perturbed orbits of a few NEOs).
- The Flyby Visualisation Tool (FBVT) offers a high accuracy visualisation of the NEOs that have one or more close approaches to Earth, also in a 3D environment (see Figure 4 for a sample close approach of Apophis in 2029).

2. A TOOLKIT FOR ALL

The main goal of the NEO Toolkit is to provide helpful observational and graphical support to astronomers in the NEO field.

For instance, a combined use of the OPT and SCDT may help any astronomer (amateur or professional) with all the necessary information to perform successful NEO observations from any place in the world.

The OPT allows selecting and calculating sub-arcsecond precision ephemerides for any of the available objects in the three available databases (see Sec. 3). These calculations can be filtered by any observational and physical restrictions that the astronomer desires to impose. Plus, the SCDT locates the targets against the sky background for an improved planning.

However, the NEO Toolkit is not necessarily limited to the most technical use cases. Tools like the OVT or the FBVT have a large potential for outreach and educational purposes.

For instance, the OVT offers a scale depiction of the global situation of asteroids and comets in a 3D Solar System environment. It may plot the Keplerian and (when available) perturbed orbits of any near-Earth

[1] https://neo.ssa.esa.int/

asteroid (NEA) and comet contained in the previously mentioned databases, as well as locating other asteroid collections associated as groups, families or by spectral class. One of the most relevant collections of NEOs is the NEOCC Risk List[2]. This list is a catalogue of all objects for which a non-zero impact probability has been computed. Focussing on the NEOs, the OVT can also identify those that may have a close approach to Earth (even past known impactors) and feature them with high mathematical detail in the FBVT. While the OVT offers a general view of the different elements in the Solar System, the aim of the FBVT is to act as a graphically and mathematically precise zoom-in over the NEOs that will have a close approach within 3 Lunar distances with respect to Earth. Even the impactors, objects that were detected before colliding with Earth (e.g., the latest one detected, 2022WJ1), can be visualised up to the estimated impact point.

3. RESOURCES OF THE NEO TOOLKIT

The NEO Toolkit is daily updated with the latest known NEOs, and it uses the large NEOCC database as its main resource for physical and orbital data. It is also supported by data from the NEO Confirmation Page (NEOCP) of the International Astronomical Union's Minor Planet Centre (IAU – MPC) and Jet Propulsion Laboratory's Small-Body Database of Near-Earth Comets (JPL – SBDB).

The system that continuously populates and updates the NEOCC database is Aegis, PDO's orbit determination and impact monitoring software (described in detail in Faggioli et al.[3]).

Last, the reliability and high computing power of the NEOCC servers supports the smooth operation of all the components of the NEO Toolkit.

[2] https://neo.ssa.esa.int/risk-list

[3] *Aegis: ESA's Planetary Defence Office Orbit Determination and Impact Monitoring Software*. Faggioli et al. - This conference.

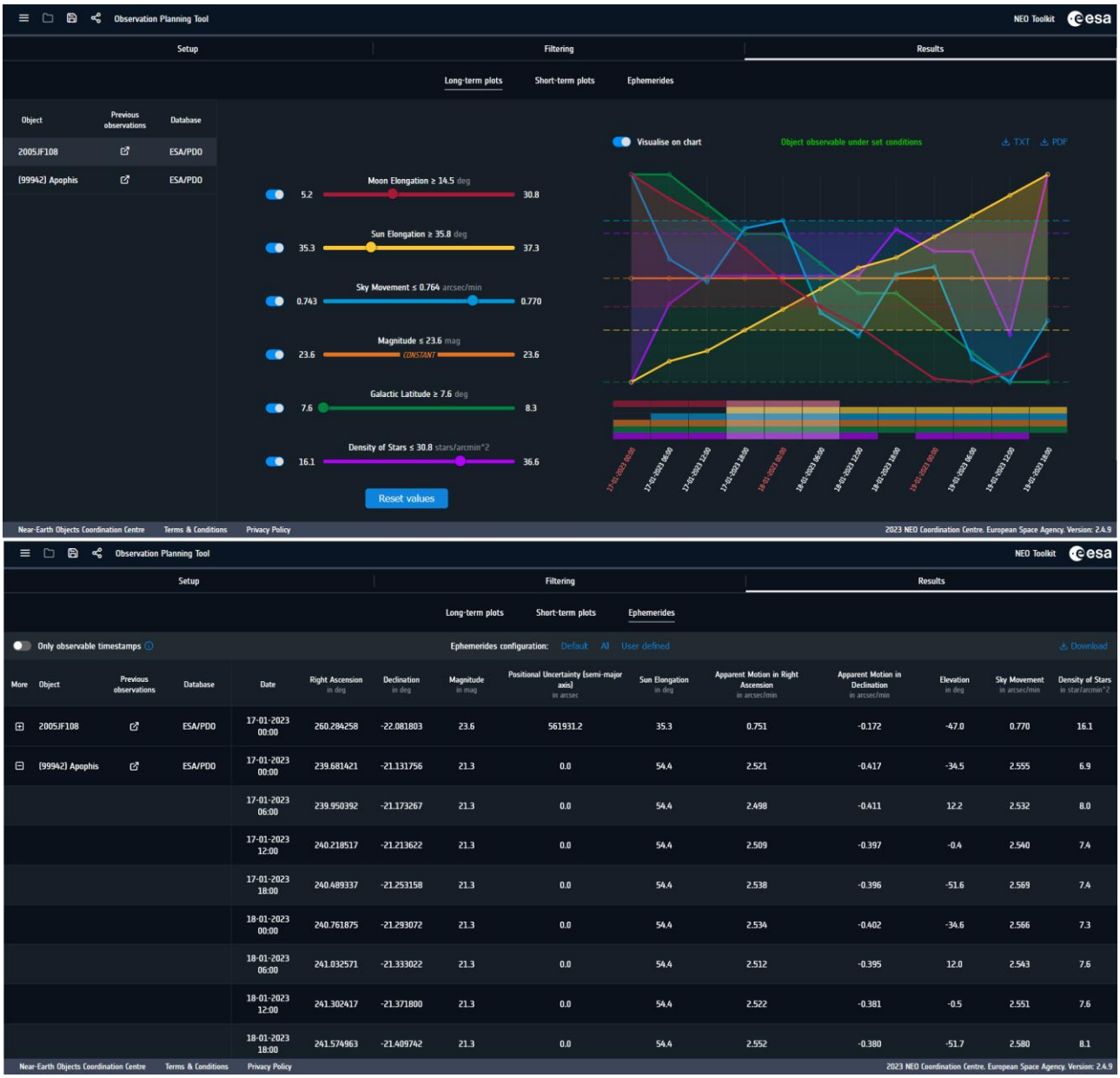

Figure 1. Top, the Long-term plots section of the Observation Planning Tool showcases the evolution of the most relevant physical parameters for a successful observation along the selected time interval, in this case, for the sample NEO 2005JF108. Bottom, an image of the Ephemerides section, reflecting a selection of parameters (11 out of the 30 available) calculated for Apophis (displayed) and 2005JF108 (hidden).

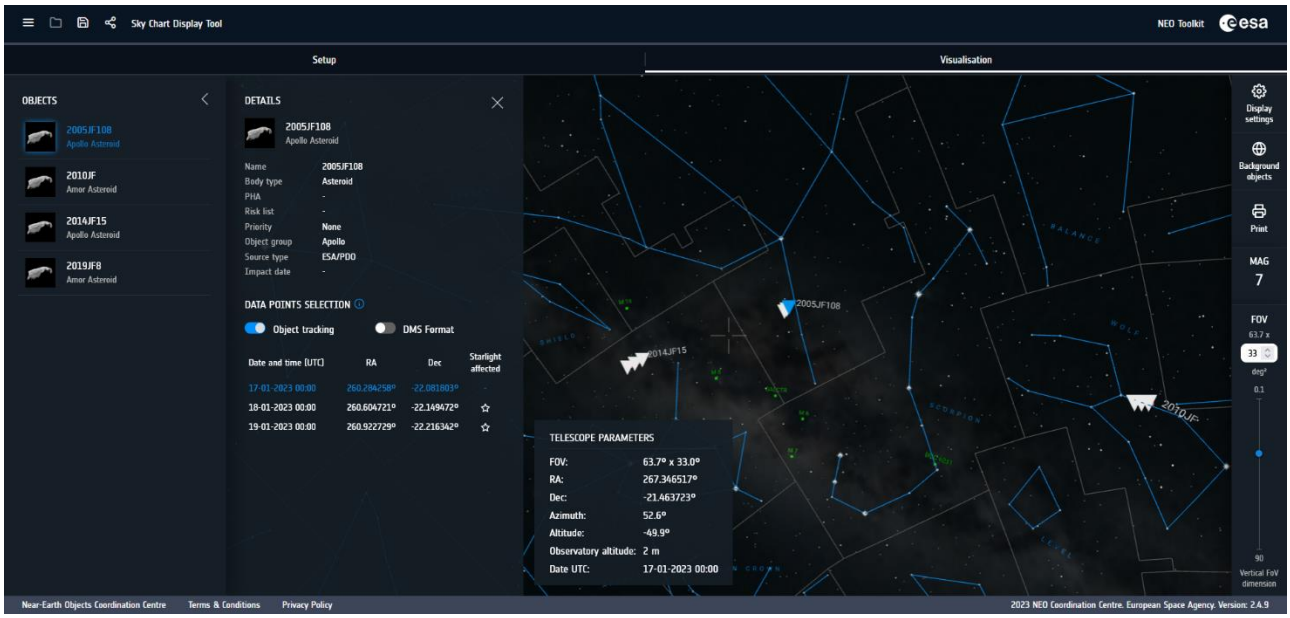

Figure 2. The Sky Chart Visualisation Tool (SCDT) showing the daily positions of three NEOs of the list in the sky from Koschny Observatory (B12) in Noordwijkerhout along the period from 17 to 19 January 2023.

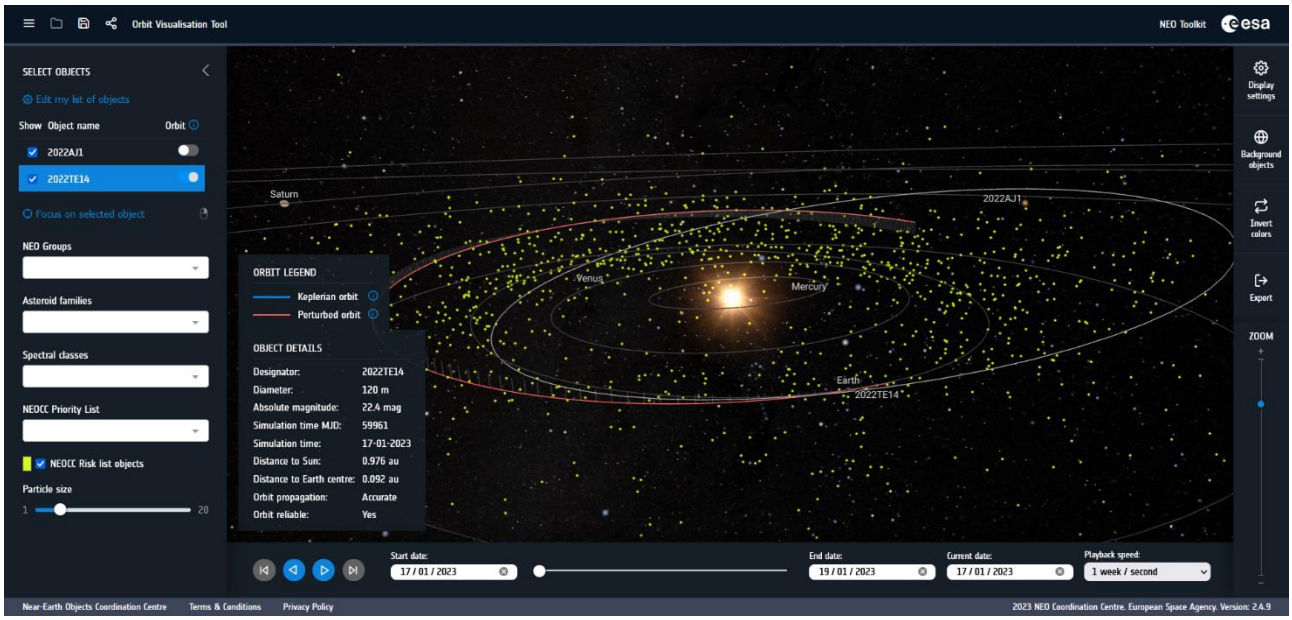

Figure 3. The Orbit Visualisation Tool showing the Keplerian orbit of 2022AJ1 (grey orbit), a 1-year worth of the perturbed orbit of 2022TE14 (red orbit) and the current elements of the NEOCC Risk List (yellow points). The Sun, some planets, and their orbits (dimmer grey) are also shown.

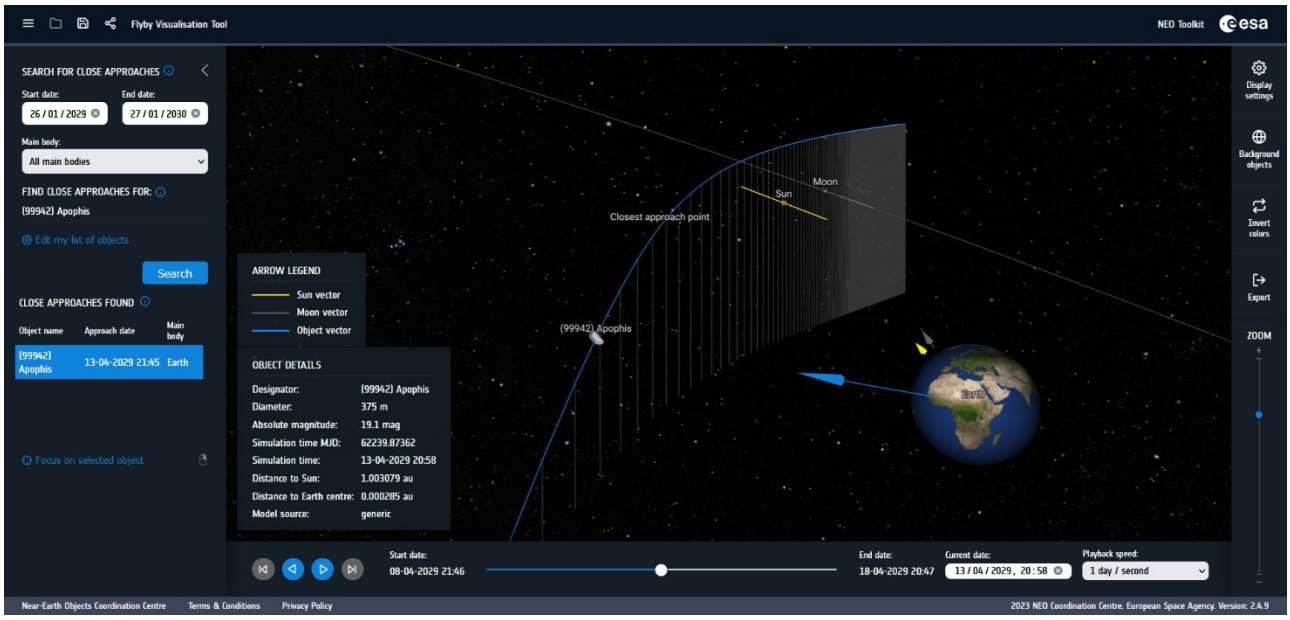

Figure 4. The Flyby Visualisation Tool (FBVT) showcasing the immediate 5 days before and after the future close approach of Apophis (size not to scale) on 13 April 2029. The vertical lines represent the elevation of the orbit over the Equatorial plane.