



(Modified and updated from the OSIRIS-REx Target Asteroids! website at <https://www.asteroidmission.org>) March 2021

1. What is Target NEOs!?

Target NEOs! is an Astronomical League observing program (listed as “NEO” ALOP). It began as a companion program to *Target Asteroids!*, a citizen science project supporting NASA’s OSIRIS-REx sample return mission to near-Earth asteroid Bennu. In addition to providing amateur astronomers with an opportunity to earn awards, the data submitted enable continued study of near-Earth asteroids by professional astronomers and spacecraft mission planners.

2. Why are amateur astronomers important partners in asteroid research?

Many advanced amateur astronomers are highly skilled, possess moderate to large aperture telescopes equipped with research quality instrumentation, and are eager to engage in research-oriented activities. Their observations can complement professional observations, provide greater geographic distribution, and create larger data sets through more frequent observing.

3. What are NEOs?

NEOs (near-Earth objects) are small solar system bodies that approach to within 1.3 AU of the Sun. Near-Earth asteroids (NEAs) are a subset of this population limited to objects believed to be asteroids rather than comets.

4. How was the *Target NEOs!* list compiled?

Carl Hergenrother, OSIRIS-REx Asteroid Astronomy lead, *Target Asteroids!* co-lead, and Target NEOs! co-coordinator, compiled the original Target Asteroids! list by selecting near-Earth objects that are larger than 200 meters in size and accessible for sample return spacecraft missions. Additional brighter, Main-belt asteroids that are analogues to (101955) Bennu have been added, too. This list is dynamic and changes as we learn more about these objects and astronomers discover new objects.

The Target NEOs! list now includes more asteroid “Targets of Opportunities” including near-Earth asteroids and the parent asteroid families to which they belong that are of interest to asteroid astronomers and spacecraft missions.

5. Where can I find the *Target NEOs!* list?

We send the list with our “Welcome to Target NEOs!” email. You may request the most recent version from one of the co-coordinators.

6. How often is the *Target NEOs!* list updated?

The *Target NEOs!* coordinators update the list when there is an asteroid of interest to the astronomical community or a favorable observing opportunity occurs, a flyby of Earth for example. Objects are not deleted



from the list though some may be downgraded in priority. When we add new asteroids, we send an email notification to registered *Target NEOs!* Observers.

7. What can my observations tell us about NEOs?

Participants in Target NEOs! can produce three different types of data depending on their instrumentation; 1) photometry, 2) astrometry and 3) spectroscopy.

- Photometry is the measurement of the brightness of an asteroid relative to standard reference stars. When photometric observations are taken over time, astronomers are able to measure an asteroid's rotation (or spin) rate, get a rough idea of its shape, derive its color, and by measuring how an object changes brightness at different phase angles (the Sun-asteroid-observer angle) even estimate its albedo or amount of light being reflected back at us.
- Astrometry is the measurement of an asteroid's position relative to the background stars. When an observer's astrometry is combined with the astrometry of other observers the orbit of the asteroid can be computed. Knowing the orbit is required for predicting the motion of an asteroid into the future. These not only allow the object to be studied in the future but may even help determine its probability of impacting the Earth.
- Spectroscopy is the measurement of the amount of light being reflected by the surface of an asteroid at different wavelengths. Similar but better than filter photometry, spectroscopy can more accurately tell us the taxonomic type of an asteroid and, in some cases, reveal minerals on the surface of an object. Asteroids appear as point sources which allow spectroscopy to be conducted with low-cost gratings such as Star Analyzers.

8. How do I get started?

The first step is to request and complete the *Target NEOs!* Registration Form and submit it to the coordinators if you are interested in participating. This action registers your interest in the project and allows you to receive updated information.

9. What kind of instrumentation do I need?

- Telescope 8" or larger (the larger the better!)
- CCD/CMOS Camera
- Broadband Color Filters (optional)
- Spectrometer or transmission grating (optional)
- Computer with internet connection
- Free astrometry software

OR

- Obtain observing time from a remote telescope service.

10. Does *Target NEOs!* provide instrumentation or software?



No. *Target NEOs!* does not provide telescopes, cameras or computers to observers. We can provide site license access to Astrometrica asteroid measuring software courtesy of Herbert Raab. Contact us for more information.

11. I don't have a telescope. How can I participate?

There are several ways in which you can participate. You may team up and use a telescope owned by a friend, astronomy club, local college or planetarium observatory. There are several private telescope services at observing locations all over the world from which interested observers may purchase telescope time. In addition, *Target NEOs!* partners with the International Astronomical Search Collaboration (IASC) for annual asteroid measuring campaigns. IASC partners with large observatories to provide images for schools and students. Then participants measure the computer images for astrometry (position with respect to background stars) and submit the data.

Contact us for more information.

12. Where can I find help?

Sources of help are:

- FAQ "Where may I find helpful on-line resources?"
- *Target NEOs!* partner organizations have websites and members who may guide you.
- Don't forget to check out your local astronomy club. You will meet friendly members who will be happy to help you. The NASA Night Sky Network and The Astronomical League websites can help you locate a club near you.
- And, of course, the *Target NEOs!* Co-coordinators are happy to answer questions.

13. I don't have a CCD camera. May I use a digital single lens reflex (DSLR) camera?

Yes. You may use a DSLR for this program. Usually DSLRs are less sensitive than commercial astronomical CCDs, but there are many people who have been using them to do accurate variable star photometry. Many of the objects on the *Target NEOs!* list are faint but a few get as bright as magnitude 14 to 16. For photometry we ask that broadband filters be used (BVRI or RGB). Photometry derived from a DSLR's 'green channel' is often similar enough to the V-band that a filter is not needed. You do not need filters to produce accurate astrometry.

14. I have an Apple computer. Can I use Astrometrica?

Most programs such as Astrometrica, IRIS, or Maxim DL require a Windows emulator, which runs Windows on the Mac. An alternative is to use one Mac computer for image acquisition and another PC for data reduction.

15. I don't have an MPC code. Is it required? How do I get one?



While we do not require an MPC code, we strongly encourage it. The procedure to obtain an assigned “MPC code” (Minor Planet Center observer’s code) requires observing “a number of low-numbered minor planets each on pairs of nearby nights” for asteroids numbered between 40 and 40000 (not too bright; not too faint). The MPC recommends starting with main belt asteroids. This is a good step before attempting some of the faint, fast-moving asteroids on the *Target NEOs!* list. See the following sites for more information:

<http://www.minorplanetcenter.net/iau/info/Astrometry.html#HowObsCode>

<http://www.minorplanetcenter.net/iau/info/Astrometry.html#begin>

16. When should I make observations?

Because not all asteroids are visible at the same time or in the same part of the sky, the observers determine their own observing schedules. Many sky calendar software programs download the latest asteroid ephemerides (astronomical positions) from the IAU Minor Planet Center (MPC) that allow the observer to plan the evening’s observing session. The MPC, Lowell Observatory, and JPL-Center for NEO Studies have helpful aids for planning observing sessions:

<http://www.minorplanetcenter.net/iau/MPEph/MPEph.html>

[Small Bodies What's Observable? http://ssd.jpl.nasa.gov/sbwobs.cgi](http://ssd.jpl.nasa.gov/sbwobs.cgi)

<https://asteroid.lowell.edu/main/astorb>

17. How do I know what asteroids are observable from my location?

Many sky calendar software programs download the latest asteroid ephemerides (astronomical positions) from the IAU Minor Planet Center (MPC) that allow the observer to plan the evening’s observing session based on location. See the helpful aids for planning observing sessions listed above. Go to the *Target NEOs!* list and copy asteroid designations. Then paste into your favorite ephemeris program.

18. What types of observations are needed?

Observations consist of *at least 3* images processed for flat field and dark subtraction and corresponding electronic files processed for one or more of the following:

- photometry (to 0.1 magnitude accuracy, if possible); V or R is best;
- astrometry (precise, accurate positions against a star field); and
- spectroscopy while difficult for these faint objects is welcome.

19. What are some helpful hints from the experts?

Make sure:

- You are observing the correct asteroid and that it is a real object (not an image defect);
- There are reference stars in the field of view for astrometry and/or photometry (12 or more standard stars is best but not always possible);



- Use the proper order fit correction (when in doubt start with lower order fits);
- Place the asteroid of interest near the center of the field;
- For photometry, we recommend use of the UCAC4 or CMC-14 or PPMXL catalog if the UCAC4 does not cover the location of the asteroid. (Astrometrica and other astronomical software have access to these built in).

20. What is required for each asteroid observation?

The following information is required for each observation (containing 3 *or more* digital or photographic images) of the asteroid acquired over a ½ hour (or more) interval that illustrate the correct asteroid has been identified.

The ideal report consists of at least three images corrected for flat field and dark subtraction, along with corresponding photometry and astrometry in standard IAU Minor Planet Center format (used by the most popular astrometry programs). Please include a copy of the configuration file (*.cfg) used to process the images in case we need to compare with other catalogs or observations.

Refer to the excellent NASA Amateur Observing Program here: <https://aop.astro.umd.edu/> and Brian Warner's Guide to Photometry: <https://www.minorplanet.info/ObsGuides/Misc/photometryguide.htm> See the *Target NEOs!* Observer Instructions for more detailed information.

21. What software or star catalogs are recommended?

There are many excellent software packages available that allow the observer to locate asteroids, capture images, and "track-and-stack" many images to reach the really faint asteroids. While *Target NEOs!* does not endorse particular software, some resources are:

For finder maps:

- C2A (planetarium software)
- Planetarium programs such as HN Sky and others

For astrometry:

- Astrometrica
- MPO Canopus/PhotoRed
- Pinpoint/Maxim DL

For photometry:

- MPO Canopus/PhotoRed
- Landolt Reference Stars
- Carlsberg Meridian Catalog 14 (CMC-14)
- The AAVSO Photometric All--Sky Survey (APASS)
- Astrometrica



22. What format should I use to report astrometric observations?

The recommended format is the International Astronomical Union Minor Planet Center (MPC) format that can be found here: <https://www.minorplanetcenter.net/iau/info/ObsDetails.html>

(See FAQ: “How do I submit my observations?” for an example). Note that some software save the data in this standardized format already. Additional email annotations are welcome.

23. How do I submit my observations?

Email your images and MPC reports as attachments to the co-coordinators at meteorite@cox.net and carlhergenrother@gmail.com or provide a “Box” website where they can be downloaded. Submit them as you make them. When you have reached the minimum 10 or 25 asteroids to earn a certificate, email a summary to the coordinators. . Don’t forget to submit the MPC reports to the MPC repository.

24. What will happen to my observations?

We will collect the observations and provide awards earned. The images may be re-processed and combined with others for use in scientific publications. Data from the reports are archived in existing data repositories at the International Astronomical Union’s Minor Planet Center (MPC) when you submit them by email to the MPC. Astronomical researchers may use data to refine orbits, create composite lightcurves, determine asteroid sizes, rotation periods, shape models, compositions, and evaluate the presence of companion asteroids. Your data remains yours and you are free to provide it to any other asteroid program you desire. You may also publish your work independently of the *Target NEOs!* program (for example, in the Minor Planet Bulletin, or the journals of the ALPO and BAA). Even if you publish your work independently you can still be part of any *Target NEOs!* publications containing your data.

25. How do I receive credit for my observations?

Observers who earn awards by observing 10 and 25 asteroids receive a certificate (and pin for advanced award) and are listed in the Astronomical League database on the Astronomical League website. They will be acknowledged in related publications that use the data.

26. How do *Target Asteroids!* and *Target NEOs!* programs leave a legacy?

Target Asteroids! and *Target NEOs!* programs build a data legacy beyond the OSIRIS-REx mission lifetime as more nations move out into the Solar System because, as a stand-alone program, it does not require the mission to continue. The data repositories will be accessible to future scientists and mission planners.

27. Where may I find helpful on--line resources?

- General asteroid information
 - [NASA Amateur Observers’ Program](#)
 - [International Astronomical Union Minor Planet Center \(IAU MPC\)](#)
 - [Center for Near-Earth Object Studies \(CNEOS\)](#)
 - [Near-Earth Object Human Space Flight Accessible Targets Study \(NHATS\)](#)



- Interesting discovery information and orbit illustrations
 - [Center for Near-Earth Object Studies - Orbits](#)
- Observation planning
 - [International Astronomical Union Minor Planet Center ephemerides service](#)
 - [Lowell Observatory](#)
 - [IAU--MPC Guide to Minor Body Astrometry](#)
 - [Minor Planet.Info \(Brian Warner\)](#)
- General making asteroid observations
 - [IAU-MPC Guide to Minor Body Astrometry](#)
 - [Astrometrica \(Herbert Raab\)](#)
 - [Minor Planet Observer Canopus/PhotoRed software \(Brian Warner\)](#)
 - [Brian Warner's "A Guide to Minor Planet Photometry"](#)
 - [Astronomical League's Asteroid Observing Program](#)
 - [Astronomical League's Target NEOs Observing Program](#)
- Minor Planet Center format and submissions
 - [IAU Minor Planet Center](#)

28. Who are the *Target NEOs!* co-coordinators?

- Carl Hergenrother
- Dolores Hill

29. Help! I have a question not on this list. Whom do I contact?

Email your question to: meteorite@cox.net and carlhergenrother@gmail.com. One of us will reply as soon as possible.