# TC4 Observing Campaign: An Operational Test of NASA Planetary Defense Network


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## ABSTRACT

Impacts due to near-Earth objects (~90% near-Earth asteroids, or NEAs, and ~10% comets) are one of the natural hazards that can pose a great risk to life on Earth, but one that can potentially be mitigated, if the threat is detected with sufficient lead-time. While the probability of such an event is low, the outcome is so catastrophic that we are well justified in investing a modest effort to minimize this threat. Historically, asteroid impacts have altered the course of evolution on the Earth. In 2013 the Chelyabinsk meteor over Russia, which injured over 1600 people and caused ~$30M in damages, reinforced the importance of detecting and characterizing small NEAs that pose a greater threat than most large NEAs discovered so far. The NASA Planetary Defense Coordination Office (PDCO) was established to ensure the early detection, tracking and characterization of potentially hazardous objects (PHOs) and is the lead office for providing timely and accurate communications and coordination of U.S. Government planning for response to an actual impact threat. In an effort to test the operational readiness of all entities critical to planetary defense, the NASA PDCO is supporting a community-led exercise. The target of this exercise is 2012 TC4, a 20-meter diameter asteroid that is currently expected to pass by the Earth over Antarctica on Oct. 12, 2017 at a distance of only 2.3 Earth radii. The goal of the TC4 Observing Campaign is to recover, track, and characterize 2012 TC4 as a potential impactor in order to exercise the entire Planetary Defense system from observations, modeling, prediction, and communication. The paper will present an overview of the campaign and summarize early results from the exercise.


## 1. INTRODUCTION

Catastrophic collisions between planetary bodies are among the most fundamental processes that shape the course of life on Earth. Collisions are thought to have initiated planetary and asteroidal moons, transferred volatiles and organics between objects, and caused mass extinctions on Earth. It is possible that impactors delivered some of the ingredients of life itself to the Earth. The visible evidence for collisions is the large and small impact craters that dot all planetary surfaces. These impactors also deliver a significant fraction of exogenic materials that enriches the native regolith with minerals, volatiles, and organic material. The impactor population today comprises of near-Earth objects (NEOs), which is made up of ~90% near-Earth asteroids and ~10% near-Earth comets. Impacts due to NEOs are one of the few natural hazards that can cause the extinction of the human race. The best defense against such impacts is to discover these hazardous objects ahead of time so an appropriate mitigation mechanism could be explored. While impacts during a human time scale are stochastic, the outcome of such an event is so catastrophic that investing a modest effort to minimize this threat is well justified.

## 2. PLANETARY DEFENSE

Every day the Earth is impacted by small NEOs that, while sometimes producing spectacular fireballs, normally burn up harmlessly in the atmosphere. These events have been monitored and cataloged by US government sensors (Figure 1). However, the Earth is not so lucky sometimes. One of the most recent large events took place over the Chelyabinsk region in Russia where well over a thousand people were injured and thousands of buildings were damaged when a 20-meter NEA impacted on February 15, 2013. In January 2016, NASA Headquarters established an office to manage the Agency's planetary defense-related projects and coordinate activities across multiple U.S. agencies as well as with international efforts to plan appropriate responses to the potential asteroid impact hazard. The creation of the Planetary Defense Coordination Office (PDCO) is a logical and formal step forward with NASA's NEO Observations program, which began nearly two decades ago. Since the program's inception in 1998, NASA-funded efforts have discovered more than 98% of the more than 16,000 NEOs currently known. The NASA PDCO is the central body that ensures the early detection of potentially hazardous objects (PHOs). PHOs include asteroids and comets whose orbits are predicted to bring them within 0.05 Astronomical Units of Earth (~7.5 million km) and are large enough to reach Earth's surface in case of an impact (30-50 meters in diameter). PDCO is also responsible for tracking and characterizing PHOs and issuing warnings in case of potential impacts with timely and accurate communications. It is also the point body for coordinating U.S. Government response to an actual impact threat.

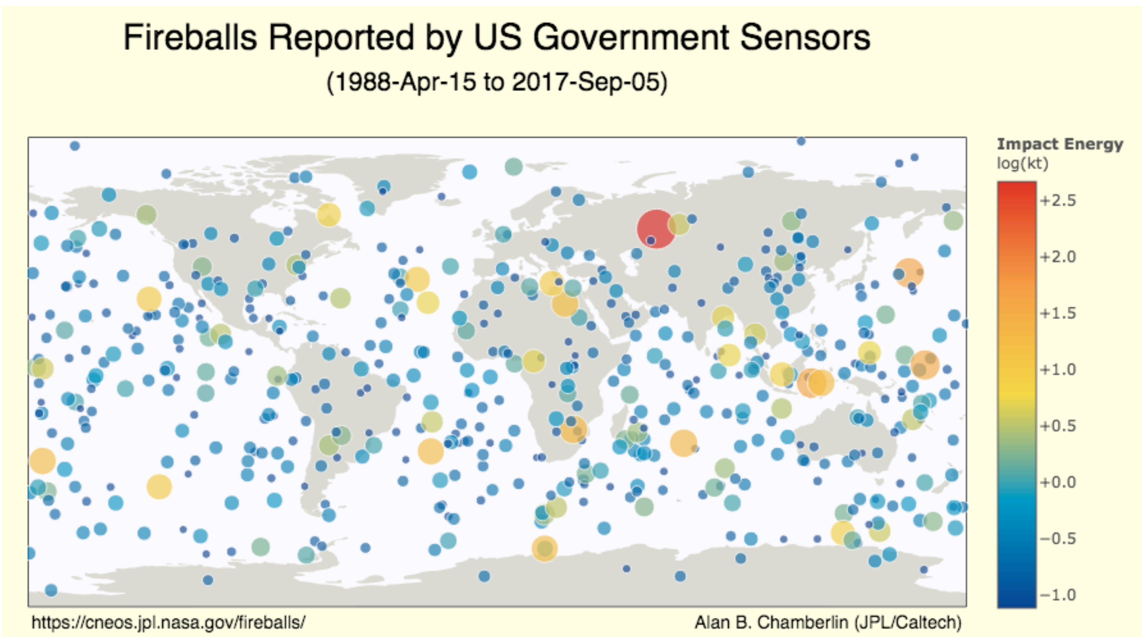


**Figure 1.** Map of the world showing fireball and bolide events and their impact energy provided by U.S. Government sensors. A fireball is defined as an unusually bright meteor that reaches a visual magnitude of -3 or brighter when seen at the observer's zenith and are created by NEOs larger than 1-meter in diameter. Fireballs that explode in the atmosphere are technically referred to as bolides although the terms fireballs and bolides are often used interchangeably. (Source: JPL CNEOS Page)

## 3. INTERNATIONAL PARTNERSHIPS

As important as it is to mitigate a potential impact event, the essential first step is to find these near-Earth objects as early as possible. To that end, NASA's PDCO leads national and international efforts to:

- detect any potential for significant impact of the Earth by natural objects;
- appraise the range of potential effects by any possible object; and
- develop strategies to mitigate impact effects on human welfare.

In conducting its work, the PDCO collaborates with other U.S. Government agencies, other national and international agencies, and professional and amateur astronomers around the world. Along those lines, NASA is the *de facto* lead entity for the International Asteroid Warning Network (IAWN).
IAWN was established in 2013 on the basis of the recommendations of the United Nations Action Team on near-Earth Objects (NEOs) for an international response to the NEO impact threat as well as the

recommendations of the Working Group on NEOs of the Scientific and Technical Sub-committee, which were welcomed by the United Nations General Assembly in its resolution of 11 December 2013. IAWN is a partnership of scientific institutions, observatories, and other interested parties performing observations, orbit computation, modeling, and other scientific research related to the impact potential and effects of asteroids. It endeavors to foster a shared understanding of the NEO hazard and optimize the scientific return on these small celestial bodies. This partnership is organized consistent with the concept developed within the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS).

The recovery effort (along with the follow-up characterization observations) of 2012 TC4 is the first time the IAWN interfaces were exercised to more efficiently coordinate and execute an actual world-wide observation campaign for an exercise to simulate a potential asteroid impact scenario.

## 4. TC4 CAMPAIGN

As part of these duties, the PDCO conducts regular planetary defense exercises within the scientific community during Planetary Defense Conferences, and with other federal entities such as the Federal Emergency Management Agency (FEMA). These exercises provide valuable information about how prepared we are in case of an impact and what are the best response practices. A key component that is missing from these exercises is a real life threat such as an impending asteroid impact. Similarly, NEO surveys, follow-up observers, characterization and threat assessment capabilities have not been exercised with a real NEO so far. Taking advantage of a close flyby of a ~20-meter diameter near-Earth asteroid 2012 TC4 in October 2017, we proposed a planetary defense exercise that would help test all these capabilities using a real asteroid for the first time. The goal of the TC4 campaign is to recover, track, and characterize TC4 as a potential impactor in order to exercise the entire Planetary Defense system from observations, modeling, prediction, and communication.

2012 TC4 is an Apollo-type NEA that was discovered on Oct. 4, 2012 by the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) located at Haleakala Observatory, Hawaii. The object was observed for seven days (Oct. 4, 2012 to Oct. 7, 2012) during its discovery apparition when it approached to within ~15.5 Earth radii. Based on this seven-day orbit, the object was predicted to make a close flyby of the Earth in on Oct. 12, 2017, but there was a large uncertainty of the close approach distance during the 2017 flyby. Participants in the TC4 campaign planned a major recovery effort involving some of the largest ground-based telescopes on the Earth. Based on these efforts, the NEA was recovered using the 8-meter Very Large Telescope (VLT) in Chile by European observers on Jul. 27, 2017. At the time of this recovery, 2012 TC4 was at visual magnitude 27, making it the faintest NEO recovery to date. These new observations enabled us to refine the flyby distance and time to 50,100±450 km at 05:42 UTC on Oct. 12, 2017. Subsequent observations by the Spacewatch survey using the 4-meter Mayall Telescope on Kitt Peak on Aug. 30, 2017 and Aug. 31, 2017 reduced the flyby distance and time to 50,170±230 km at 05:42:04 UTC on Oct. 12, 2017. Since the recovery and follow-up phase of the campaigns are drawing to a close, we are currently gearing up for characterization phase of the campaign during which we will collect rotational lightcurves, radar, visible and near-IR spectral measurements from more than 20 ground-based assets around the world.

## 5. SUMMARY

The TC4 campaign is the first planetary defense exercise that will use a real asteroid to test a global planetary defense network. We have successfully assembled an international team of observers, modelers and decision makers to recover, follow-up, characterize and model the impact hazard posed by this object. Using this team, 2012 TC4 was recovered using the VLT at a visual magnitude of 27, making it the faintest asteroid to be recovered by a ground-based telescope. Subsequently follow-up observations from Kitt Peak have narrowed down the flyby distance and time to 50170±230 km at 05:42:04 UTC on Oct. 12, 2017. We are currently gearing up for the characterization part of the campaign as we approach the flyby date.