HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
April 10, 2013

Statement of
Donald K. Yeomans
Manager, NASA Near-Earth Object Program Office
Jet Propulsion Laboratory

before the

Committee on Science, Space, and Technology
U.S. House of Representatives

Mr. Chairman and members of the Committee, thank you for the opportunity to appear today to discuss the progress and plans being made to discover, track and characterize the population of near-Earth objects that may pose threats to Earth.

The Importance of Near-Earth Objects: Near-Earth objects, commonly called NEOs, are comets and asteroids that can pass within about 28 million miles of the Earth's orbit. While icy active comets may occasionally pass close to Earth, it is the difficult-to-find, but far more numerous asteroids that are of most concern in near-Earth space today. Near-Earth objects are scientifically important because they represent the bits and pieces left over from the solar system formation process. Collisions with the early Earth likely brought much of the water and carbon-based materials that were the building blocks of life. Once life did form, subsequent collisions punctuated evolution, allowing only the most adaptable species to evolve further. We humans likely owe our origins and current position atop the food chain to these near-Earth objects.

While the vast population of near-Earth objects is a relatively recent discovery, they are of utmost importance in the study of the solar system's origin and our own origins, and they will likely play a major role in the future, providing building materials, water and fuel resources for interplanetary exploration and development. It is ironic that the near-Earth objects that are the easiest to reach for robotic or human exploration, and the easiest to exploit for their mineral and material wealth, are the same objects that represent the most serious potential threats to Earth. While finding them is important for future space resource development, we also need to find them - before they find us.

A Recent Hit and a Miss: Less than two months ago, on Friday, February 15, 2013, a 60-foot sized asteroid, traveling at 42,000 miles per hour, entered the Earth's atmosphere near Chelyabinsk in central Russia. It was heated and violently compressed by the atmospheric pressure and exploded about 14 miles above the surface, producing a descending shock wave with an energy of approximately 440 thousand tons of TNT explosives. Most of the asteroid itself was reduced largely to dust, but it also produced thousands of small fragments which fell to the ground as meteorites. Over 1,200 people were injured by the effects of the shock wave – mostly from broken glass. Given the millions of similarly sized objects in Earth's neighborhood, a collision by one would be expected about once every 100 years on average. Coincidently, only 16 hours later, a larger 130-foot asteroid called 2012 DA14 that we had been tracking for a year came from a different direction, passing within 17,200 miles of the Earth's surface, 5,000 miles within the ring of communications satellites broadcasting the news of its arrival. An approach this close to Earth's surface by an object of this size is expected to occur every 40 years or so, on average. So, on the same day, we witnessed a once in a 100-year event and an unrelated once in a 40-year event. Here we have a nice example for science teachers to show that even extremely unlikely events in nature do happen – even two on the same day.

Because it was found a year in advance, we were able to accurately predict the close Earth passage of asteroid 2012 DA14 on February 15, and we knew that it would not hit the Earth. However, the small asteroid that impacted the Earth's atmosphere over Russia arrived unannounced because it came from the direction of the Sun, and was hence unobservable with Earth-based telescopes. Discovering and identifying relatively small Earth impactors among the millions of asteroids in the Earth's neighborhood represents a significant challenge. Because there are so many more smaller asteroids than larger ones, the smaller ones hit the Earth's atmosphere more frequently. There are about ten million 20-meter sized asteroids like the one that exploded over central Russia two months ago, and their frequency of collision with the Earth is about once every 100 years, on average. When these small ones do hit, we expect them to break up in the atmosphere and cause only localized damage on the ground. Asteroids larger than one kilometer, on the other hand, could not only penetrate the atmosphere and impact the Earth's surface, they could also cause ejecta clouds that can affect weather patterns, produce firestorms and acid rain, and seriously harm global society and economics. The number of such large asteroids, however, is far smaller, only about 1000, and the frequency with which they impact the Earth is much lower, only about once every 700,000 years on average. But, the events of February 15, 2013, demonstrate that even extremely improbable events can happen, and that it is prudent to pay attention to the problem of finding and tracking all potentially hazardous near-Earth asteroids. And the focus should not be restricted to just the large near-Earth asteroids; mid-sized objects in the 100 to 500 meter range also pose a serious risk, since they could devastate an entire regional area.

The Spaceguard Goal: The population of near-Earth objects one kilometer and larger appropriately received the most attention in the early years of NASA's Near-Earth Object Observations program. In May 1998, a NASA representative announced plans to the House Subcommittee on Space and Aeronautics: NASA would find and track at least 90% of all the near-Earth objects larger than one kilometer; this became known as the "Spaceguard" goal. In December 2005, President Bush signed into law the George E.

Brown, Jr. Near-Earth Object Survey Act, that gave NASA a broader and more ambitious goal, to detect and track at least 90% of the near-Earth objects larger than 140 meters in diameter, and to characterize the physical properties of a representative sample of this population.

Significant Progress Has Been Made: When I last had the honor to address this Committee in November 2007, about 80% of the NEOs one kilometer or larger had been discovered and only a few percent of the smaller 140 meter objects. Today, the Spaceguard goal of discovering 90% of the large NEOs has been exceeded and about 25% of the 140 meter or larger sized NEO population has been discovered. Today, the discovery rate of NEOs is about 1000 per year, up 50% since 2007. The Minor Planet Center in Cambridge, Massachusetts, has 100 million observations of NEOs in its database and 27,000 observations are added daily. Fully 96% of all NEOs were discovered by NASA-funded surveys. The vast majority of all current NEO discoveries are being made by the Catalina Sky Survey, operating near Tucson, Arizona, the Pan-STARRS survey operation atop Haleakala, Maui, Hawaii, and the LINEAR survey near Socorro, New Mexico.

None of the NEOs found to date have more than a tiny chance of hitting Earth in the next century. Thus the near-term risk of an unwarned impact from large asteroids, and hence the majority of the risk from all NEOs, has been reduced by more than 90%. Assuming none are found to be an impact threat, discovering 90% of the 140 meter sized objects will further reduce the total risk to the 99% level. By finding these objects early enough and tracking their motions over the next 100 years, even those rare objects that might be found threatening could be deflected using existing technologies. For example, a spacecraft could purposely ram the asteroid, modifying its orbital velocity by a very small amount, so that over several years its trajectory would be modified and its predicted impact of Earth in the future avoided by a safe margin. The autonomous spacecraft navigation required to effect such a collision was successfully demonstrated in July 2005 when NASA's Deep Impact spacecraft purposely rammed comet Tempel 1 to better understand the comet's structure and composition.

There have also been dramatic increases in the rate with which observations have been made to understand the physical nature of these NEOs, their so-called "characterization". These include infrared observations that are used to infer asteroid sizes and compositions and radar observations that are used to determine asteroid sizes, shapes, rotation rates and whether or not an asteroid has a moon. For example, since 2007 when I last addressed this Committee, there has been a 250% increase in the number of infrared observations of NEOs made at the NASA supported Infrared Telescope Facility in Hawaii. During 2012 alone, the number of radar detections of NEOs at both the Goldstone facility in California and the Arecibo facility in Puerto Rico has tripled compared to the average of the previous ten years. Largely as a result of NASA support, there has been extraordinary progress in the last six years for the discovery and physical characterization of NEOs.

There has also been significant progress within the NEO Action Team associated with the UN Committee on the Peaceful Uses of Outer Space (COPUOS) to encourage and integrate more international efforts for NEO detections, for addressing deflection issues and for establishing protocols to be used by the international community in response to a potential NEO threat.

Possible Next Steps For Ground-Based Systems: There is still much work to be done. About 50-100 NEOs larger than one kilometer remain undiscovered, along with about 13,000 NEOs larger than 140 meters and millions of objects larger than about 30 meters in extent - the approximate minimum size for a common stony asteroid to cause significant ground damage.

It is important that the current NEO discovery surveys, operating with one to two meter-class optical telescopes continue their nightly searches and continue to improve their equipment, operations and data processing. These ground-based optical telescopes will continue to significantly add to the count of large NEOs discovered, but the current search assets will not be able to reach the goal of finding nearly all of the population of 140-meter sized objects within a reasonable time period because of their limited capability to detect these very dim objects.

The existing Pan-STARRS1 (PS1) system operates a 1.8-meter aperture telescope on the island of Maui but this instrument only focuses its attention on NEO observations for about 11% of its observing time because of other science objectives. Even so, PS1 currently provides about 25% of the NEO discoveries, second only to the Catalina Sky Survey. Suitable funding to increase the percentage of time devoted to NEO searches on Pan-STARRS1, at the expense of other science, would accelerate the current NEO discovery rate, as would the full time or part time use of a second Pan-STARRS2 telescope that is nearing completion adjacent to the Pan-STARRS1 facility on Maui.

An important planned future contributor is the Space Surveillance Telescope (SST), a 3.5-meter wide-field telescope that is being developed by MIT's Lincoln Laboratory for DARPA and the US Air Force. When fully operational in late 2014, this telescope will scan a wide region centered on the equatorial band of the night-time sky. Investigations are ongoing to better understand the efficiency with which this telescope will discover NEOs and what sort of scheduling might be intermingled with its prime mission of man-made space object surveillance to carry out these NEO observations.

The most effective, ground-based NEO detection telescope that is currently in planned development is the Large Synoptic Survey Telescope (LSST), a 8.4-meter aperture, wide-field telescope that is planned to begin operations in Chile in the early 2020s. To be funded by the National Science Foundation and a consortia of private and international agencies and universities for a variety of science programs, simulations have suggested that the shared use of LSST could catalog approximately 25% of the 140 meter sized NEOs within 5 years of operations and about 45% in ten years.

The View From Space: Especially for the population of undiscovered sub-kilometer sized objects, space-based infrared telescopes would be a more efficient discovery system than the current ground-based optical surveys. This is because asteroids emit considerable heat, not just reflected sunlight, and this heat makes them bright in the infrared wavelengths, but these wavelengths are also unfortunately heavily filtered by the Earth's atmosphere. In addition, the view from an observatory orbiting the Sun interior to the Earth's orbit would have far better viewing coverage of hazardous objects farther away from Earth. Furthermore, a space-based telescope would not have to deal with downtime due to weather and daylight. Ground-based telescopes have difficulty distinguishing a large, dark asteroid from a small, bright asteroid, often making asteroid size measurements very uncertain. On the other hand, space-based infrared measurements can infer an asteroid's size with an uncertainty of only about 10% and its reflectivity to about 20%. These types of measurements were demonstrated in 2010 when the highly successful NEOWISE effort mined asteroid discoveries, sizes and reflectivities in the data produced by the Wide-field Infrared Survey Explorer (WISE) satellite.

If the goal is to complete the survey of 140 meter sized objects more quickly, the 2010 National Research Council report entitled "Defending Planet Earth" indicated that a space-based infrared telescope in either a Venus-like orbit or interior to the Earth on the Sun-Earth line (L1 point) would be far more efficient finding NEOs than would existing, or planned, ground-based optical surveys. For the more numerous population of smaller NEOs that can still do significant ground damage, an infrared telescope at L1 would be well positioned to find those smaller objects making close Earth approaches. A successful space-based IR survey telescope in a Venus-like orbit would be very effective in discovering NEOs further in advance and providing positional observations unavailable from Earth-based telescopes. Together these observations would allow a faster refinement of an asteroid's orbit so that impact predictions could also be updated more quickly. Hence these space-based observations might provide an early "all clear" and avoid otherwise unnecessary concern and unneeded deflection mission planning or initiation.

Threat Mitigation vs. Threat Warnings: For the millions of small NEOs, in the range of 30 to 50 meters, it would be extremely challenging to find the majority of this population far enough in advance to first determine which ones represent a threat and then deflect them safely away from Earth. And meeting such a challenge may not be cost effective. It may be sufficient to simply detect these small asteroids a few days or weeks prior to Earth impact so that appropriate warnings could be made and evacuations undertaken similar to hurricane emergencies in the unlikely case where populated areas of Earth would be threatened. A warning of this type would also assure affected nations that the coming explosive blast would be a natural phenomena rather than a hostile act.

The NASA-funded ground-based ATLAS system currently under development at the University of Hawaii is a relatively low cost, wide-field telescopic survey designed to patrol the entire accessible night sky every night to provide suitable impact warnings for small asteroids on near-term Earth impacting trajectories. Simulations suggest that the ATLAS system, consisting of 3 to 4 sites worldwide, will find almost all objects larger than 30 meters coming at us from the night sky and provide a week's warning time. Current search programs are designed to find larger potentially hazardous objects well in advance of a predicted impact so that existing technologies (e.g., spacecraft rendezvous and impacts) could be employed to deflect the object out of harm's way. One of the issues with which policy makers will need to wrestle is where to draw the line as to the minimum NEO size that represents so large a threat as to require deflection attempts. Objects below that limit would then require only advance warning. Cost benefit studies would shed some light on this issue.

Summary: The NASA-supported NEO observations program is proceeding extremely well, and the rate with which NEOs are being discovered and physically characterized is increasing each year. There are viable options for accelerating the current NEO search efficiencies either using next-generation, ground-based optical surveys or the even more efficient space-based infrared surveys. The use of both ground-based and space-based assets would be the most effective option for quickly finding 90% of the NEO population larger than 140 meters. Robust future NEO search programs and the attendant physical characterization efforts could provide a large number of target bodies for scientific study, for future robotic and human exploration and for future resource development. These same surveys could also identify which of the discovered NEOs represent potential future threats and do so with enough time to either deflect the object, or warn of its arrival.