Recovery of Near-Earth Object Science Lost Due to the Demise of Arecibo

A white paper from the Small Bodies Assessment Group

The United States Congress has mandated that NASA search for and characterize near-Earth objects (NEOs) and formulate plans to mitigate their destructive potential. As described in the *National Near-Earth Object Preparedness Strategy and Action Plan* (DAMIEN, 2018), radar astronomy is one of the key elements in NASA's array of capabilities to study and track NEOs. The Arecibo Observatory was the foremost facility with "resolution [that] greatly exceed[ed] that available from any optical telescope on the ground or in near-Earth space and is matched only by 'flyby' and exceeded only by rendezvous spacecraft missions" (National Research Council, 2010). Radar astrometry remains the most precise Earth-based technique for refining knowledge of asteroids' trajectories and for predicting future Earth encounters. Radar studies that characterize the size, morphology, roughness, and surface texture of individual NEOs provide key information for mitigation strategies and support asteroid spacecraft missions. The importance of radar astronomy to NASA's goals is emphasized in the last planetary science Decadal Survey:

> "Ground-based facilities that receive NASA support, including …Arecibo… all make important and, in some cases, unique contributions to planetary science. NASA should continue to provide support for the planetary observations that take place at these facilities." (National Research Council, 2011).

The collapse of Arecibo has dealt a severe blow to NASA's ability to characterize NEOs. The Small Bodies Assessment Group (SBAG) recommends that NASA partially offset this loss to NEO science and to planetary defense in the near-term by supporting increased radar observations by other facilities. The following set of options are listed in approximate priority order and are summarized in Table 1.

- **Additional radar observations with the DSN antennas at Goldstone, to observe as many potentially detectable asteroids as possible.** Planned improvements to the power systems and transmitters for the Goldstone Solar System Radar on DSS-14 would improve reliability, minimize downtime, and should be completed without undue delay.
- **Encouragement of additional radar observations with the DSN antennas at Canberra**. Work with Australian collaborators at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to install a new receiver at the Parkes 64-m radio telescope, which would increase the number of asteroids potentially detectable from the southern hemisphere.
- **Continuation of programs at the Green Bank Telescope (GBT), potentially with NASA support for a dedicated allocation of radar observing time.** The Green Bank Telescope has been a key receiver for bistatic radar observations and now has a low-power transmitter that can be used for a limited number of asteroid radar observations. NASA should also explore supporting the proposed development of a high-power radar transmitter for GBT, with the recognition that such a transmitter would be a major investment.
- **Encouragement of additional asteroid observations with the Haystack Observatory and establishment of an agreement between NASA and Lincoln Laboratory for public release**

of asteroid radar data. The Haystack Observatory is capable of making high-resolution observations of dozens of very small asteroids that make close flybys to Earth.

- **Establishment of a collaboration with the Istituto Nazionale di Astrofisica (INAF) to demonstrate radar observations from Madrid and Sardinia**. DSN antennas at Madrid could potentially conduct bistatic radar observations of selected asteroids, receiving with the 64-m Sardinia Radio Telescope operated by INAF, but this capability has not yet been used.
- **Encouragement by NASA for the European Incoherent Scatter Scientific Association (EISCAT) and the Fraunhofer Institute & ESA to consider additional asteroid radar work.** The EISCAT UHF and EISCAT3D ionospheric radars and TIRA orbital monitoring radar in Europe could potentially observe dozens of asteroid targets over the next several years.

Table 1. SBAG's suggested improvements to current radar capabilities.

Facility	Description	Estimated additional cost to NASA	Comments
DSN: Goldstone	Increased radar observing time with GSSR and DSS-13	Operating costs	
Green Bank Phase 1 transmitter Phase 2 proposal	NEO observations Development of new transmitter	Operating costs $30 million +	Collaborate with NSF
DSN: Canberra Receive with Parkes (Australia)	DSS-43 80 kW klystron New Parkes receiver	Operating costs ~$300,000	Collaborate with CSIRO
Haystack	NEO observations with existing transmitters and receivers	Operating and startup costs	Operated by MIT, Lincoln Laboratory; requires proposal to NASA.
DSN: Madrid Receive with Sardinia (Italy)	DSS-63 or DSS-53 transmitters	Operating costs	Collaborate with INAF
EISCAT UHF EISCAT 3D (Scandinavia)	Available through 2025. Buildup of new system; available after 2022.		Encourage planetary radar observations by EISCAT consortium
TIRA (Germany)	NEO observations with existing transmitter and receivers.		Encourage planetary radar observations by Fraunhofer Institute, ESA.

These options only partially replace Arecibo's capabilities. The total number of asteroids potentially detectable with all radar facilities currently available or under construction combined is still significantly less than the number potentially detectable with Arecibo. The population of radar-detectable NEOs is now dominated by very small (<50 m) objects passing very close to Earth (Naidu et al. 2016). Many larger and more distant objects that were detectable by Arecibo cannot be observed with current radar facilities, including those listed in Table 1.

SBAG also supports the development of a new facility to replace Arecibo and recommends that NASA continue to consult with NSF and/or other relevant agencies about the Arecibo collapse and the process for deciding what happens next with the site in order to ensure that the implications for NEO observations are included.

References

Interagency Working Group for Detecting and Mitigating the Impact of Earth-bound Near-Earth Objects (NEOs) (DAMIEN) of the National Science and Technology Council. 2018. National Near-Earth Object Preparedness Strategy and Action Plan. https://www.hsdl.org/?view&did=812290 .

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