1. What is the name of the proposed milestone?

FIRST RADIO ASTRONOMICAL OBSERVATIONS USING VLBI, 1967

IN THE EARLY MORNING OF 17 APRIL 1967, RADIO ASTRONOMERS USED THIS RADIOTELESCOPE AND A SECOND ONE AT THE ALGONQUIN RADIO OBSERVATORY LOCATED 3074 KM AWAY TO MAKE THE FIRST SUCCESSFUL RADIO ASTRONOMICAL OBSERVATIONS USING VERY LONG BASELINE INTERFEROMETRY. TODAY, VLBI NETWORKS SPAN THE GLOBE, EXTEND INTO SPACE AND ARE ROUTINELY USED FOR BOTH RADIO ASTRONOMY AND GEODESY.

2. What is the location of the proposed milestone?

Dominion Radio Astrophysical Observatory, 25 km from Penticton, British Columbia, Canada.

3. In what IEEE section does it reside?

Vancouver

4. In What Year or Years was the work performed?

The DRAO 26-m radiotelescope was completed in 1959 and the Algonquin 43-m radiotelescope in Ontario was completed in 1966. As a result, Canada had two major radiotelescope installations in 1967. (Although the Algonquin radiotelescope ceased radio astronomy operations in 1988, DRAO is still very active today.)

Discussions of the feasibility of interferometry spanning the continent, i.e., Very Long Baseline Interferometry or VLBI, began in 1960, and technical developments continued until success was achieved in 1967.

The work was originally reported in: N. W. Broten, T. H. Legg, J. L. Locke, C. W. McLeish, R. S. Richards, R. M. Chisholm, H. P. Gush, J. L. Yen, and J. A. Galt, "Long baseline interferometry: A new technique," *Science*, vol. 156, pp. 1592-1593, 1967.

The historical context of the work has been presented in: K. I. Kellermann and J. M. Moran, "The development of high-resolution imaging In radioastronomy," *Annual Review of Astronomy and Astrophysics*, vol. 39, pp. 457-509, Sep. 2001. (The DRAO VLBI work is described on pp. 479-480.)

5. What is the historical significance of the work (its technological, scientific, or social importance)?

From its Canadian beginnings, VLBI has become an important technique for both radio astronomy and geodesy. It has been the central theme of over 3,500 papers in the scientific literature over the ten-year period 1999 to 2008, and the flow continues unabated.

VLBI provides better angular resolution than any optical telescope and can reveal details within some of the most distant objects detectable. Astronomers use VLBI to provide crucial tests of General Relativity, to demonstrate definitively the existence of black holes in galaxy cores, to test the fundamentals of high energy physics, and to look back to the early Universe.

VLBI techniques also permit the position of objects on Earth and in the solar system to be measured with millimetre accuracy with respect to the ultimate reference frame, distant quasars. Such techniques are now routinely used: (1) to precisely track spacecraft on voyages to the planets and (2) to provide the basis for precise geodetic surveying including important studies of the movement of crustal plates, earthquake prediction and Earth rotation. See, for example,

J. L. Yen, P. Leone, G. A. Watson, J. K. Zao, J. Popelar, W. T. Petrachenko, G. Feil, W. H. Cannon, P. Mathieu, P. Newby, H. Tan, R. D. Wietfeldt, and J. A. Galt, "'The Canadian geophysical long baseline interferometer," Radio Science, vol. 26, no. 1, pp. 89–99, Jan.–Feb. 1991.

In the late 1970s the community of Canadian VLBI scientists developed a new concept, an array of large radio telescopes spread across the entire breadth of Canada working together, using VLBI techniques to form one giant imaging telescope, the Canadian Long Baseline Array. The project fell victim to a barren funding climate for science in Canada in the 1980s but the concept was used by US scientists to build the Very Long Baseline Array (the VLBA) across that country. The VLBA has been a scientific success story since its completion in 1993.

VLBI research continued with the DRAO 26-m Telescope until 1988. In 1990 DRAO scientists and engineers became involved with the first extension of VLBI techniques into Earth orbit. The DRAO team designed and built a forefront correlator, a special-purpose digital processor that combined signals from a Japanese space telescope, VSOP, with ground based radiotelescopes around the world. VSOP was launched in 1997 and operated with superb effectiveness until 2003, achieving many world firsts.

6. What features set this work apart from similar achievements?

Short-baseline interferometry had been used in radio astronomy for high-resolution imaging since the 1940's. Cables or (sometimes) radio links were used to connect two or more radio antennas to signal processing equipment. The distance or baseline between pairs of antennas in such interferometers was initially small but gradually became larger over time. It soon became clear that important astrophysical questions could be answered only by building interferometers with baselines greater than any cable or radio link could span. The proposed IEEE Milestone will recognize the first successful radioastronomical observation made using such techniques.

7. What obstacles (technical, political, geographic) needed to be overcome?

The principal technical challenge was to establish two independent receiver systems with individual clocks and recording devices that were sufficiently stable to maintain coherence over periods of many minutes and sufficiently sensitive to detect the very weak radio astronomical signals.

Great ingenuity was applied to operating within a limited budget and adapting existing equipment to the task. For example, the first VLBI observations were collected using surplus video recorders that had been purchased from the Canadian Broadcasting Corporation.

8. Describe fully the intended site(s) of the milestone plaque(s). The intended site(s) must be publicly-accessible, secure, and have a direct connection with the achievement (e.g. where developed, invented, tested, demonstrated, installed, or operated, etc.).

The Dominion Radio Astrophysical Observatory (DRAO) is a National Facility for astronomy operated by the National Research Council Canada. It is operated to support the research of the Canadian astronomy community, mostly consisting of researchers in universities.

The plaque will be installed on the base of the DRAO 26-m radiotelescope that was used as the western site of the first successful VLBI radio astronomical observations in April 1967 observations. This location will be readily accessible to the several thousand members of the general public that visit the Observatory site each year.

For related background, see
http://www.nrc-cnrc.gc.ca/eng/facilities/hia/radio-astrophysical.html
http://www.ieee.ca/millennium/drao/DRAO_about.html

9. Please give the address(es) of the plaque site(s) (GPS coordinates if you have them). Also please give the details of the mounting. If visitors to the plaque site will need to go through security, or make an appointment, please give the contact information visitors will need.

The address of the Observatory is 717 White Lake Road, Kaleden, B.C., Canada V0H 1K0. The plaque will be mounted on the base of the DRAO 26-m radiotelescope. Its geodetic coordinates are +49° 19' 15.18", -119° 37' 13.31".

10. Are the original buildings extant?

Yes. Although the receivers and control systems have been completely upgraded, both the DRAO 26-m radiotelescope and the original observatory building appear as they did in 1967 and are still fully used.

11. How is the site protected/secured, and in what ways is it accessible to the public?

The site is accessible to the public seven days a week from Easter to Thanksgiving and five days a week through the winter. When staff are not present, the DRAO site is secured by electronically operated access gates and a security system.

Observatory scientists typically give tours to 1000 school students throughout the year. A professional guide typically gives weekend tours to 5000 visitors per year. Casual self-guided visitors to the site typically number 5000 each year. The Observatory holds an Open House every September that typically attracts over 1000 visitors each year.

12. Who is the present owner of the site(s)?

The site is owned by the National Research Council Canada (NRC).

13. Has the owner of the site agreed to have it designated as an Electrical Engineering Milestone?

Yes.

14. Please specify the IEEE Organizational Unit(s) which have agreed to sponsor the Milestone nomination.

IEEE Vancouver Section