

Dear Dr. Ulvestad,

The NRAO User's Committee (UC) represents a broad and diverse community of researchers who use the unique facilities and infrastructure provided by the National Radio Astronomy Observatory. Our role is to provide NRAO with representative feedback from the larger community. We are writing you to comment on the recent Portfolio Review Committee report which we feel would have a significant negative impact on the entire astronomical community if it is implemented.

The UC recognizes the enormous effort that the members of the Portfolio Review Committee (PRC) put into the report. While it should come as no surprise that the UC strongly disagrees with some of the conclusions of the report, this does not reflect our appreciation of the efforts of the PRC members. The UC is aware that the charge to the PRC was restricted and would like to suggest that a broader scope might have produced a more optimal solution.

The PRC clearly has the health of the community over the next decade in mind. In particular, their support of the individual grants program as well as mid-scale projects is crucial. Without astronomers to use the facilities, there is no reason to have the facilities. Likewise, the mid-scale projects return exciting science on short time scales, develop new technologies to power next generation instruments, all while training the next generation of instrument builders. Without strong support in both these areas, astronomy in the United States will surely begin to wither over the next decade.

However, the UC feels that there are several major flaws in the PRC report that warrant serious consideration. These can be divided into issues surrounding the assumptions and inputs guiding the PRC and the conclusions of the PRC regarding NRAO assets.

Assumptions and inputs guiding the Portfolio Review:

- The overriding guide to the PRC report was the Decadal Survey, New Worlds, New Horizons (NWNH) written by the National Academy of Sciences. The PRC worked to implement major new initiatives despite the fact that the NWNH recommendations were based on a wildly optimistic budget projection which is as much as a factor of two higher than what is now expected. It is not at all clear that, presented with a realistic budget scenario, the NWNH report would come to the same conclusions. The assumption that the large scale initiatives of NWNH must be pursued at any cost should be reconsidered.

- The NWNH report considered the entire US investment in Astronomy while the PRC only considered NSF investment. This narrow view makes it appear that radio astronomy comprises a very large fraction of the available resources. The combined NASA and private support for optical astronomy dwarfs spending in the radio. An apparent equitable treatment of optical and radio facilities within NSF funding alone results in inequitable damage to the radio astronomical program. The proposed plan results in the loss of unique capabilities forever. These potential losses need to be balanced with a delay in new major initiatives.

Conclusions of the Portfolio Review concerning the VLBA:

- Recent upgrades to the capabilities of the VLBA have made it a new facility with new science to exploit. These upgrades include a wider bandwidth accompanied by a factor of 2.8 increase in sensitivity, new C-band receivers. The wide-field VLBI mode provided by the new software correlator allows the conversion of the VLBA into a survey science machine, an unrivalled capability which will be able to distinguish starburst galaxies from AGN in faint radio source counts.
- The VLBA provides a unique capability that is not matched by any other facility, either planned or currently operating. All other existing VLBI networks are ad-hoc, heterogeneous arrays, with only a few brief observing windows each year. Unlike other facilities being considered by the PRC, whose scientific capabilities overlap with other telescopes, it is highly unlikely that the special capabilities of the VLBA could be recreated if it is shut down.
- The VLBA has followed recommendations of 2006 Senior Review to seek international and other non-NSF support. This has allowed continued operations at a significantly reduced cost to NSF. Should the facility be fully divested, it is likely that telescope time would be available only to a few institutions.
- The VLBA has an important role to play in high angular resolution follow-up studies. One example is the recent discovery of an Earth-mass cloud on an impact trajectory with the super massive black hole at the Galactic Center. Due to initially strike SgrA* in 2013, only the VLBA has the ability to monitor this impact over long time scales (several years) and with ~ 12 Schwarzschild radius resolution. Once-in-a-lifetime opportunities like this would be a casualty of the loss of the VLBA.
- The VLBA provides critical links between the radio bands and high energy studies, including complementarity with Fermi Gamma-ray Space Telescope. Only the VLBA can produce spatially resolved maps on linear scales that correspond to scales on which TeV and GeV photons are thought to originate.
- The phasing project at ALMA is scheduled to lead to VLBI capability by 2015. This will immediately form ultra-high sensitivity VLBI baselines in new north-south orientations with the VLBA. The VLBA-ALMA combination will double VLBA sensitivity and angular resolution enabling a range of high-impact science including parallax measurements of SgrA*, sensitive maser and pulsar astrometry, and exquisitely sensitive AGN polarimetric imaging. For M87, possibly the most studied relativistic jet in the sky, imaging can be done on linear scales of ~ 10 Schwarzschild radii.

Conclusions of the Portfolio Review concerning the GBT:

- NRAO's Green Bank Telescope (GBT) is a new facility. Commissioned in 2000, it did not reach its full high frequency capability until 2009. New instruments are being developed to take advantage of the GBT's broad frequency coverage, especially at the high frequency end. While NRAO could, perhaps, be chastised for not taking advantage of the high frequency science earlier, the new director is aggressively pursuing new and exciting millimeter science enabled by the GBT's large unblocked aperture.

- The PRC focuses mainly on the GBT's operation at 21 cm. This would be consistent with the assertion that Arecibo is an acceptable alternative to the GBT. Examination of recent papers from both observatories shows that most of Arecibo research involves 21 cm measurements. In contrast, users of the GBT published papers on Galactic HII regions (a new catalog), high-z galaxy ISMs, nearby galaxy 21cm interstellar medium (ISM), a planetary debris disk, a pulsar discovered in a supernova remnant, a nearby molecular cloud structure, the cosmological Sunyaev-Zel'dovich effect, ultradeep 90 GHz continuum field measurements (important for subtracting point sources from CMB maps), ISMs in host galaxies with active galactic nuclei, relic emission in a galaxy cluster, the ISM wake of a red giant star, the GBT-led resurgence of cosmic flow measurements, and a new ISM molecule (HNCNH).

- Arecibo has access to only 10% of the sky on any given day (30% over the course of the year) compared to the GBT's 85% sky access. Equally important is the limited tracking ability of Arecibo which dramatically restricts the integration time on a given source. These become especially relevant for gravitational wave studies with pulsars discussed below. The utility of a pointable telescope to study objects in the sky considerably exceeds that of a fixed telescope. This allowed the GBT to make the first high redshift ($z \sim 0.8$) 21cm intensity mapping detections, and plans are underway for a large 21cm redshift survey funded by a foreign partner (Taiwan). Additionally, while Arecibo's larger aperture provides high point source sensitivity at 21 cm, the GBT benefits from its location in a radio quiet zone. This results in less radio frequency interference (RFI) contamination of redshifted lines.

- NWNH stated that, "The large sky visibility of the GBT is strongly complemented by the better sensitivity, though limited sky coverage, of Arecibo; both are needed to detect and study nanohertz gravitational waves." The GBT will be the primary instrument of choice for unlocking the secrets of gravity waves via pulsar observations. This is backed up by Figure 9.8 in NWNH which gives the probability of detecting a stochastic background. The Arecibo observations improve on the GBT, not the other way around. While it is true that pulsar studies can continue on Arecibo, the study of gravity waves using pulsars will be essentially lost if the GBT is no longer available.

- The 100 m Effelsberg telescope is not an adequate replacement for the GBT at shorter wavelengths. The GBT's much more accurate surface provides significantly better antenna efficiency at 90 GHz. One hour on the GBT would take over 100 hours on the Effelsberg telescope. Nevertheless, the Effelsberg telescope continues to do fantastic work at longer wavelengths and the German astronomical community continues to support and operate the facility.

- High frequency bolometer arrays on the GBT will survey large regions rapidly to find targets and calibration sources for ALMA. While CCAT could fill this role as well, it could be a decade or more away. CCAT is primarily targeting the 400 micron to 2 mm range leaving a gap in coverage from 3mm to 1 cm. Finally, the plan for running the CCAT appears to be much like the URO program with a relatively small fraction of the observing time going to the community (10-20%). CCAT cannot be considered a substitute for the proven performance of a facility that already exists, the GBT.

- NWNH report highlights a few of the exciting instruments on the GBT that would make significant headway under many of their scientific themes. "Three types of cameras are envisioned, including (1) a

100-pixel heterodyne camera for wavelengths of 2.6 to 4.3 mm and a 64-pixel heterodyne array for 10 to 17 cm, (2) a phased-antenna array for 20 cm, and (3) a 1,000-pixel bolometer array for 3 mm, as well as associated efforts in integration and packaging of receiver elements, high-speed analog-to-digital conversion, and data transmission. These new instruments will enhance searches for gravitational waves using millisecond pulsars (CFP Discovery), studies of atomic and molecular gas content and evolution and astrochemistry throughout the Milky Way (PSF 1) as well as in galaxies nearby (GAN 1, 2) and at cosmological distances (GCT 2, 3), the characterization of galaxy clusters through the SZE (GCT 1), and the statistics of stellar remnant spins from pulsar timing (SSE 4, 5).”

- Some researchers and students are fortunate and belong to institutions which can afford to gain access to privately-held or recently divested observatories. NRAO is one of the only facilities in country that provides access and substantial observational support to all. Divesting the GBT will represent the loss of one of the last truly open telescopes in the world. While ALMA will make up for some of this, the US has only a fraction of the time. ALMA is a very expensive operation, observations are complex, and observing time will be highly competitive. On the GBT, astronomers and students from smaller schools focusing on undergraduate education can learn, propose, and execute important programs. This is unlikely to be the case on ALMA.

- The GBT is now hosting a series of new instruments led by university-based groups with significant student involvement. The GBT’s willing and knowledgeable staff enables this kind of collaboration. While mid-scale projects like ACT partially fill this role, they do not produce observatory class instruments for use by the entire community. CCAT is a closed consortium which, at least for now, will be building instruments internally. So, with the URO program gone, the GBT is one of the last places where a University group can propose an ATI-level program to build a state-of-the-art instrument for a world-class telescope.

Conclusion:

The last decade has seen astronomy evolve beyond traditional electromagnetic boundaries with multi-frequency investigations and surveys becoming the norm rather than the exception. As a prime example, ALMA will draw on a broad user base extending well outside traditional radio astronomy. The fiscal realities of the coming decade demand actions to balance the status quo with the desire to answer the new and compelling questions which appear on a regular basis in astronomy. The goal is to emerge as a vibrant community with the skills and infrastructure required to complete the next generation of research. While NRAO must play a role in this process, divesting the VLBA and the GBT is not the answer. We urge the NSF/AST to consider the points made in this letter and to develop a plan which includes a more aggressive NSF funding profile combined with cost saving by the entire astronomical community, including NRAO. The result should not involve the loss of productive and irreplaceable assets. While this might result in a delay for new programs, it will ensure the United States will not lose the unique VLBA and the new and powerful GBT.

Sincerely,

The NRAO Users Committee

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