THE LUNAR RADIO ARRAY. J. Lazio[1], C. Carilli[2], J. Hewitt[3], S. Furlanetto[4], and J. Burns[5] for the LUNAR Consortium[6] [1]Naval Research Laboratory, Lazio@nrl.navy.mil, [2]National Radio Astronomy Observatory, [3]Kavli Institute for Astrophysics & Space Research, MIT, [4]UCLA, [5]U. Colorado, Boulder, [6]NASA Lunar Science Institute.

Cosmology and Astrophysics with the Highly-Redshifted 21-cm Line: Hydrogen is the dominant component of the intergalactic medium, and neutral hydrogen (H I) displays a hyperfine spin-flip transition at a rest wavelength of 21 cm (1420 MHz frequency). The feasibility of observing this redshifted H I line has excited interest because it offers the chance to extend current cosmological data sets by orders of magnitude[1,2]. Through detailed mapping of the H I line brightness temperature, it may be possible to determine the distribution of hydrogen from the present day to a redshift $z \sim 100$. This unprecedented data set would constrain the properties of the inflation era, detect signatures of any exotic heating before the first star formation (e.g., dark matter decay), and constrain properties of "dark energy" by tracking the evolution of the angular scale of the baryon acoustic oscillations. It would also provide a wealth of astrophysical data on the first galaxies, including the properties of the first stars and black holes.

The Moon as an Astronomical & Cosmological Platform: The lunar *farside* is the only site in the inner solar system for observing the highly-redshifted 21-cm line:

No Human-generated Interference. Civil and military transmitters make heavy use of the relevant spectrum (e.g., FM radio), and ionospheric refraction causes interference in the HF band used for international communication to be independent of location on Earth. Terrestrial transmitters can be much stronger ($\sim 10^{12}$) stronger than the H I signals. The Moon reduces such interference to a negligible level.[3]

No (Permanent) Ionosphere. The Earth's ionosphere produces phase errors that limit radio observations (in addition to reflecting interference from distant transmitters). The Moon's ionized layer disappears during lunar night.

Shielding from Solar Radio Emission. When the Sun bursts, it is the strongest celestial source at these wavelengths. The only mitigation for solar radio emissions is physical shielding, such as observing on the farside during lunar night.

Mission Description: The LRA concept draws on the experience from ground-based radio interferometers. The LRA will be located on the lunar farside, e.g., Tsiolkovsky crater, with components delivered using a heavy-lift vehicle (e.g., Ares V) and lander (e.g., Altair cargo). Unpacking and antenna deployment will be handled by rovers. A central processing unit on the lander will serve as a control and communications center.

Technology Development. We have identified technologies that need to mature over the next decade in order to enable the LRA: (1) Long-wavelength, low-mass science antennas; (2) Ultra-low power, radiation tolerant electronics; (3) Autonomous, low power generation; (4) Low-mass, high-capability, autonomous rovers; and (5) High data rate, lunar surface data transport. Many of these technologies are broadly relevant, beyond just the LRA.

Roadmap. Many ground-based radio arrays have been preceded by scientifically productive prototypes, and ground-based arrays will provide important scientific pathfinding for the LRA. An illustration of the staged deployment of lunar radio telescopes is

I. One dipole deployed on an orbiter or on the near side, such as the Lunar Array Precursor Station (LAPS), a concept developed under the Lunar Sortie Science Opportunities (LSSO) program. Key science would be searching for the H I signature from the Epoch of the First Stars or probing the lunar ionosphere.
II. A small, near-side interferometer, such as the Radio Observatory for Lunar Sortie Science (ROLSS), a concept developed under the LSSO program. Key science would be particle acceleration in the inner heliosphere. Deployment could be done either robotically or with astronaut assistance in a sortie scenario.
III. A modest-sized interferometer. Key science would include extending ground-based observations of the 21-cm line and potentially detecting magnetospheric emissions from extrasolar planets. Deployment would be largely robotic.
IV. The fully capable LRA on the far side.

The Lunar University Network for Astrophysics Research (LUNAR): Science and technology development for the LRA are being conducted in LUNAR, one of the inaugural 7 teams in the NASA Lunar Science Institute (NLSI). A LUNAR key project is Low Frequency Astrophysics & Cosmology, involving (1) Refinement of theoretical tools for predicting highly-redshifted H I signals; (2) Array concept and algorithm development; and (3) Science antenna technology development.

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