Lunar Imaging Radio Array (LIRA) - draft 2005/1/20

LIRA is the code name we are using for an alternate and/or follow-on to SIRA that would be lunar-based. There is no mandatory coupling between LIRA and SIRA. At present, this effort is intended primarily to assist in the development of the NASA Sun-Solar System Connections Roadmap, the NASA Science Instrument and Sensor (SIS) Capability Roadmap, and any other roadmap we can donate it to. Mention of a lunar-based VLF radio observatory in the Roadmap is good promotion for any SIRA-type mission, plus it has a logical connection to exploration of the moon. The similarity of the names LIRA and SIRA is deliberate (but feel free to something better).

The format in which our discussions will be contained are the mission design, described below. And the PowerPoint template from the SIS workshop for Radio Imaging: LF – HF bands; this includes timelines and costs at each stage that we are still working on.

<u>Assumptions:</u>

1) LIRA will focus on solar and space weather targets; it has both science and exploration goals and justifications. “Astrophysical” targets, like the epoch of reionization, may require the far-side lunar observatory, which is not the LIRA baseline mission.

2) So, LIRA is not intended to be the mission to do the best mapping of the astrophysical universe. The goal will be for a mission configured to do the best SSSC science and applied research.

3) LIRA should be a mission that dovetails with lunar exploration (which will become clearer as the exploration schedule).

4) It is not bad (and might be considered good) if there are components of LIRA that require development. This is addressed in the technology development sections of the roadmap template

<u>Basic design:</u>

Lunar site – equatorial and near side. Close to, but shielded by natural geography from the planned manned site, if possible; alternately, placed in the same quadrant as the planned manned site for space weather issues. Site must be relatively smooth for antenna deployment by rover; a nearly flat (2-D) surface is desirable. If the manned infrastructure goes to a polar location, that is also a reasonable site for the first (of 2) radio observatories.

Lunar landing – need to land one rover to deploy antennas in addition to antenna units, cabling, correlator station, and command/data transceiver. Presumably, landing is a controlled descent of a rocket stage, followed by a drop with airbag protection.

Astronaut intervention – not needed for deployment or routine operation; potential of repair visits could be useful

Antenna configuration and deployment – Baseline will use a thin (1 mil) sheet approximately 1 m wide on which the wiring is deposited. Specifically, the antennas (crossed bowtie style broadband dipoles) and balanced feedlines would be made of very thin layers of conductive material (superconductive at lunar nighttime temperatures) coated on flexible dielectric plastic sheeting. The deployment would create a radial spoke geometry, with one long sheet forming each spoke. The power/correlation/data transmission/control center is at the center of the radial geometry. The antenna elements would be spaced 1-4 wavelengths apart along each sheet. The spoke arrangement automatically provides a quasi-Gaussian distribution of (u,v) sampling, which is desired for high dynamic range imaging. Note that there are no preamps in the sheeting in this design; losses along the line are tolerated to simplify the design.

The non-redundant rover would deploy (roll out) one sheet at a time. The sheet would be connected by flexible cable to the lander/correlator unit, so that no electrical connections need to be established by the rover.

Number of antennas – This approach has the major advantage of permitting large numbers of antennas; let's assume 8 spokes with 1024 antennas each, yielding a total of more than 8,000 antennas.   Considerable effort will be required to constrain mass and volume. Correlation and image processing will likely need to be done on site due to bandwidth limitations on the link to Earth.

Frequency range and angular resolution – Similar to SIRA, but increase the top frequency to 60 MHz, i.e., 30 kHz – 60 MHz. The entire bandwidth will be sampled. The sheets will be 5 km long, yielding a 10 km baseline and ~30 deg angular resolution at 60 kHz. At 60 MHz, the theoretical resolution of ~2 arcmin is finer than the limits imposed by scattering. This may also be true at <100 kHz.

Sampling – 8 bit, Nyquist sampling of 60 MHz band

Correlation and aperture synthesis – follow in the footsteps of LOFAR/LWA. Correlate data on site; post integrate to reduce downlink data rate further or complete image processing at site. Power requirements would be greatly reduced with a custom correlator.

Electrical power source(s) – presume Prometheus-based nuclear generation; assume 2 kW required routinely; solar array backup should be considered for some functions.

Data downlink/command uplink from/to Earth – single high gain antenna (with backup?) at the central correlator site

Mission life - ~10 yrs

Alternatives to consider:

- Substantially fewer, robust antenna units with wireless transmission. Surface curvature requires repeaters.

- Processing/power requirements versus pre-existing satellite network for transmission of visibilities to ground.

Descope options:
- Fewer antennas
- More limited sampling
- Reduce to 30 MHz

Action items:

RJM - LOLA vertical and horizontal resolution – Dave Smith, Arlen Bartels, LRO 2008
RJM - Solar sail materials – Tim VanSant
DJ - No need for preamplification over 5 km
LD - Status of Prometheus power generators
LD – Info on environmental hazards relative to thin sheets/wires
RH - Any additional details on relay sat network
KW - Info on lunar regolith electrical parameters – should be in 1990 books