Response to Call for White Papers for Universe Roadmap

**Exploring the Universe with the DSN Arrays**

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The NASA Deep Space Network is developing the next generation of telecommunications infrastructure. We point out that these facilities could be unique instruments for astronomical exploration. We recommend that the design goals of the DSN Arrays be considered in this context and that cost/benefit analyses be performed with a view to constructing the DSN Arrays to allow astronomical research. The studies would need to be completed by the end of 2006 to meet the DSN Array construction schedule.

**Background**

The DSN is planning to construct three large-aperture arrays for deep space telecommunications. Each will consist of 400 12-m antennas distributed over 1 km circles operating at 8 and 32 GHz. These will be located at approximately 120° separation in longitude with at least one in the southern hemisphere. The arrays will have 3½ times the collecting area of the VLA and 40 times that of ALMA (which will provide 32 GHz coverage of the southern sky). The arrays will have correlators, for example to allow radio sources to be used for phasing the array.

Compact, sensitive large arrays would have unique capabilities for astronomy. Numerous studies have documented the importance of the science they would enable, and the strong community support for a Square Kilometer Array is evidence of this. As an intermediate step, a compact configuration has been proposed for Phase Two of the VLA Extension. If the DSN Arrays were able to do radio astronomy comparably to the VLA, they would be extremely powerful instruments.

**Science Goals**

The unique potential capabilities of the DSN Arrays include studies of:

- **Cosmology**: Observations of fluctuations in the cosmic microwave background (CMB), and measurement of the CMB polarization, are the most definitive probes we have cosmology in the very early universe;
- **Dark Energy**: Measurements of the Sunyaev-Zeldovich effect in galaxy clusters as a function of epoch reveal the effect of dark energy over the course of cosmological evolution;
- **Galaxy Formation and Evolution**: The change, over time, of the mass of galaxies from atomic matter, to molecular matter to stars will be studied by means of spectroscopic observations of redshifted spectral lines;
- **Extreme Physics in the Vicinity of Black Holes**: The DSN arrays will anchor VLBI arrays used to image the physical processes leading to acceleration of relativistic particles near the Schwartzschild radius of supermassive black holes in the nuclei of active galaxies;
• **Star Formation Astrophysics:** The DSN arrays will reveal the physical conditions—temperature, gas density, chemistry and magnetic field—that catalyze star formation;
• **Structure of the Milky Way:** Continuum observations of radio emission from the Galaxy will allow us to untangle the contributions of relativistic particles and magnetic fields to the energetics of the Galaxy.

**Description of the Proposed Tasks**

The proposed tasks would be studies to determine whether it is technically, fiscally, and programmatically feasible to include astronomy requirements in the specifications for the DSN Arrays.

The principal task would be to consider to what research areas the DSN Arrays could make the greatest contributions. These would drive the modifications needed in the present design. They may include:

• **Baselines:** This spacing has been chosen to minimize antennas shadowing each other when tracking a spacecraft at low elevation. The current plan would provide an angular resolution equal to the VLA D configuration but 0.2 times the filling factor of the E configuration.
• **Front End:** The current feed design for the DSN Arrays will allow operation from 8.0 to 8.8 GHz (X-band) and 31 to 38 GHz (Ka-band). However, it may be possible to design a cooled feed/amplifier combination which would work from 2 to 40 GHz.
• **RF Bandwidth:** To reduce the risk of interference, the DSN Arrays will have bandpass filters to restrict the receivers to the bands allocated for deep-space-to-earth downlinks.
• **Number of IF Channels:** The current plan calls for two.
• **IF and Data Bandwidth:** The current design has an intermediate frequency bandwidth of 500 MHz with corresponding digitizer rate and correlator speed. The Expanded VLA (EVLA) will have 4 GHz of bandwidth at X-band and 8 GHz at Ka-band with √8 and 4 higher sensitivity.
• **Correlator:** This will operate with a maximum bandwidth of 512 MHz on two IFs with at least 256 channels. It will be possible to trade the number of channels to produce cross-polarization products.

Given the science drivers and desired specifications for the DSN Arrays, a joint science and engineering team would need to achieve a balance between performance and cost. This would need to be done with an awareness of what fraction of time would be available for radio astronomy on the DSN Arrays.

Since 1990 about 5 to 6% of the time (2500 – 3000 hrs) in the DSN has been used for astronomy. In support of VSOP, it was 15% and 12% in 1996 and 1998 respectively. An additional consideration is that the current mission set is based on the use of 34-m and 70-m antennas so these could be serviced with 12 and 50 antenna subarrays. Until a new generation of missions is launched, the array may be significantly underutilized.

**Programmatic Issues**

The DSN Array which will be built in Australia will be unique into the foreseeable future (just as the Canberra 70-m is now) because of its declination coverage.

Adding capability to the DSN Arrays may also have benefits for mission support such as multi-polarization, multi-spacecraft communications (i.e. at Mars) and improved spacecraft navigation.

The Astronomy and Astrophysics Advisory (Illingworth) Committee (AAAC) was formed to “assess and make recommendations regarding coordination of astronomy and astrophysics programs at NSF and NASA.”. One obvious issue is the interoperability of the DSN Arrays, the EVLA and the SKA. This white paper advocates an urgent call for proposals to study possible science uses of the DSN Arrays, the technology challenges, and the cost and schedule implications of adding science requirements for the DSN Arrays.