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Data generation and products of the DSA-2000 radio camera

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The 2000-antenna Deep Synoptic Array ([1]; DSA-2000) is a radio telescope planned for construction between 2026-2028, which will deliver unprecedented capabilities for radio astronomy in the 0.7—2GHz band. I will describe the challenges faced by the DSA-2000 in the generation and delivery of its diverse data products, and how these challenges are being overcome.

The DSA-2000 will consist of around 2000 5-m fully steerable dishes, arranged in a 19x15km configuration in a valley in eastern Nevada, in the United States. Each dish will be equipped with a dual-polarization wideband uncooled receiver operating between 0.7—2 GHz; system temperatures of less than 25K and aperture efficiencies of around 0.7 are expected [2]. Stringent requirements (e.g., sub-arcminute pointing, <1mm surface accuracy) are placed on the performance of the dishes and receivers to enable deconvolution-free imaging in the radio camera, as discussed below. The dishes are served by optic-fiber and power infrastructure, and analog signals are brought to a central processing building over fiber. The central processing building houses a radio camera front-end (RCF) for digitization and channelization of data from each antenna, a radio-camera processor (RCP) for real-time interferometric imaging, a fast time-domain (FTD) system for the real-time discovery of sub-second transient emission and pulsars, and a DAT system for the aggregation and presentation of data products to a public archive. When complete in 2028, the DSA-2000 will begin a five-year public survey program including a cadenced all-sky survey (65% time) reaching a final depth of 0.5 micro-Jansky rms noise over 31,000 square degrees of the sky, and an ambitious pulsar timing program for the detection of low-frequency gravitational waves (25% time). The remainder of the time will be spent on deep fields and the follow-up of gravitational-wave events, and commensal surveys for pulsars and fast transients will always be ongoing. All data will be public with no proprietary period.

The DSA-2000 is only feasible as an imaging telescope if images are produced in real time, a concept termed the radio camera. This is because it is not feasible to store visibility data for future processing: given 12,359 frequency channels of interest (including zoom bands for spectral-line science), a required integration time of 1.5 s, and approximately 2,000,000 baselines, the visibility data rate is at least a few tens of PB per day. To enable real-time imaging, several requirements must be met by the array pont-spread function (PSF). These include low far sidelobes, polarization purity, and stability. We have embarked on a forward-modeling program that determines the corresponding requirements on the instrument, including the antenna, analog signal chain, flagging of radio-frequency interference (RFI), calibration, and mosaicking and stacking of the final images. Simultaneously, significant efforts are underway to develop a high-throughput streaming pipeline to implement the real-time imager on graphics processing units (GPUs). The current design is verified to meet the system requirements. I will describe the major features of this system.
The DSA-2000 (FTD) system faces similar and complementary challenges to the imaging system, in the large required throughput (e.g., 9 million beams will be searched in real time for fast transients), but also in the capability for autonomous low-latency data-product generation in a changing observing environment. I will describe how these challenges are being overcome, with the adoption of AI/ML tools for orchestration of the system.

1. G. Hallinan, et al., "The DSA-2000 — A Radio Survey Camera," *Astro2020: Decadal Survey on Astronomy and Astrophysics, APC white papers*, **255,** September 2019, doi: 10.48550/arXiv.1907.07648.
2. J. Flygare, et al., "Wideband Low-Loss Feed Design for the DSA-2000 Ambient Temperature Array in Radio Astronomy," *2024 IEEE International Symposium on Antennas and Propagation and INC/USNC-URSI Radio Science Meeting (AP-S/INC-USNC-URSI)*, Firenze, Italy, 2024, pp. 5-6, doi: 10.1109/AP-S/INC-USNC-URSI52054.2024.10686435.