ALMA to receive central correlator and digital transmission system upgrades

February 8 2023

Technician Juan Carlos Gatica checks electronics on the ALMA correlator. For this task, he's using supplemental oxygen at the high-altitude site. ALMA was recently approved for significant upgrades to the correlator, or brain, of the telescope. Additional upgrades were approved for the Digital Transmission System (DTS), the array's information highway. Credit: Carlos Padilla, NRAO/AUI/NSF

The Board of the Atacama Large Millimeter/submillimeter Array (ALMA)—an international collaboration in which the National Science Foundation's National Radio Astronomy Observatory (NRAO) is a partner—has approved multi-million dollar upgrades for the development of a second-generation correlator and a digital transmission system (DTS). As part of the ALMA2030 Wideband Sensitivity Upgrade, these projects aim to double and eventually quadruple the correlated bandwidth of the array.

Central to the ALMA2030 upgrades, the Second Generation ALMA Correlator—the "brain" of the array—is a type of supercomputer that combines the individual signals from each antenna to create exquisite images of astronomical objects. The new correlator will improve the current one's already highly refined ability to process and combine data and increase the sensitivity of astronomical images and the flexibility of making them.

"While ALMA's current correlators are already some of the fastest supercomputing signal processors in the world, the Second Generation Correlator will be capable of producing 200, and ultimately 400 times more data per second along with an increased sensitivity equivalent to adding more than 1000 hours of observing time per year," said Crystal Brogan, ALMA-North America Program Scientist and the ALMA Development Program Coordinator at NRAO.

"The initial expansion in system bandwidth by a factor of two, and eventually four, will enhance the science throughput for all areas of ALMA science from the most distant galaxies to our Solar System. The Second Generation ALMA Correlator will also enable high spectral resolution at wide bandwidth for the first time—affording an unprecedented view of the kinematics and chemistry of star and planet formation."

The $36 million project will take approximately six years to complete and combines the hardware and firmware expertise of scientists and engineers at the National Research Council of Canada (NRC) and the software expertise of NRAO's Data Management and Software Department. Additionally, experts at the Massachusetts Institute of Technology's Haystack Observatory will be assisting with the implementation and testing of the Phased Array aspects of the new correlator. The project is led by the NRAO's North American ALMA Department.

"The new correlator provides the foundation for the rest of the Wideband Sensitivity Upgrade (WSU). With the project's approval, the WSU has moved from plans to construction. The international ALMA collaboration will work together to deliver this project, and by the end of this decade, we'll see the results in amazing new science," said Phil Jewell, Director for ALMA-North America.

The upgraded Digital Transmission System (DTS)—a collaboration between NRAO's Central Development Laboratory (CDL) and the National Astronomical Observatory of Japan (NAOJ), also a partner in ALMA—will act as an expanded information highway, increasing the amount of data that can travel from each of ALMA's upgraded receivers to the upgraded correlator by a factor of eight.

"The DTS is an exciting collaboration with our colleagues at NAOJ and will provide a higher-capacity digital path for data from the upgraded receivers to the ALMA Talon Central Signal Processor. The project leverages our expertise in photonics and digital signal processing and will be built using state-of-the-art hardware, enabling a wide range of improvements," said Bert Hawkins, Director of CDL.

Alvaro Gonzalez, East Asia ALMA Program Manager at NAOJ added, "The new ALMA2030 DTS will be based on the latest high-speed data-

transmission standards and use commercially available technology as much as possible. As a collaboration between NAOJ and NRAO, we will combine the best aspects of technology and know-how from the two partners. The DTS will be designed to support the goal of 4 times increase of instantaneous bandwidth of ALMA receivers and also the eventual increase of the distance between antennas, up to around 75 km, for improved angular resolution."

Phase 1 of the DTS upgrade—approved for ~US$800,000—aims to produce a prototype of the new end-to-end system by 2026 and will be followed by a Phase 2 production proposal.

NRAO's and NA ALMA's central role in the ALMA2030 upgrades extends beyond the correlator and DTS and includes the conversion of the Operations Support Facility to house and operate the new correlator, additional infrastructure and support systems, and receiver upgrades. CDL has already commenced work to upgrade ALMA's 1.3mm (Band 6) receivers after receiving approval and Phase 1 funding in late 2021. The Band 6v2 receiver prototype is expected in 2025, allowing for the build-out of an entirely upgraded set of Band 6 receivers for ALMA that will increase the quantity and quality of science measured in wavelengths between 1.4mm and 1.1mm.

Upon completion, ALMA2030 will realize upgrades to most ALMA receivers resulting in increased bandwidth and sensitivity, complete replacement of the ALMA digital signal chain—digitizer, digital transmission system, and correlator—and installation of new fiber cables connecting ALMA's Operations Site to its Operations Support Facility, and develop associated control, data acquisition, and data processing software.

"An already immensely powerful observatory, ALMA has uncovered the secrets of protoplanetary disks and the unseen gas and dust that drives

the formation of stars, planets, and galaxies. These upgrades will help us see further than ever before and process this information faster and more clearly," said NRAO Director Tony Beasley. "With each upgrade, we are quite literally building the future of radio astronomy."

ALMA Director Sean Dougherty added, "This is a very exciting moment for ALMA. The approval of these two major components of the Wide-Band Sensitivity Upgrade—a new data transmission system and future-forward correlator—will extend the science capabilities of ALMA enormously across all fields of science."

"This exciting project ensures ALMA continues to operate and provide fantastic observations," says Joe Pesce, NSF Program Officer for ALMA. "Improved capabilities enabled by the upgraded correlator will lead to new discoveries about our universe and advancement of science."

"This project will significantly improve the sensitivity, flexibility and efficiency of the telescope," said Brent Carlson, Research Officer at the NRC's Herzberg Astronomy and Astrophysics Center and the NRC's Principal Investigator for the correlator project.

"The Second Generation ALMA Correlator will allow much more spectral information from radio sources to be imaged instantaneously, giving scientists access to a colossal amount of new data. The ability to do spectral scans efficiently at such high resolution is unprecedented and will keep ALMA at the forefront of scientific discovery."

Provided by National Radio Astronomy Observatory