VLA Visitor's Center Interpretive Master Plan

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TEAM

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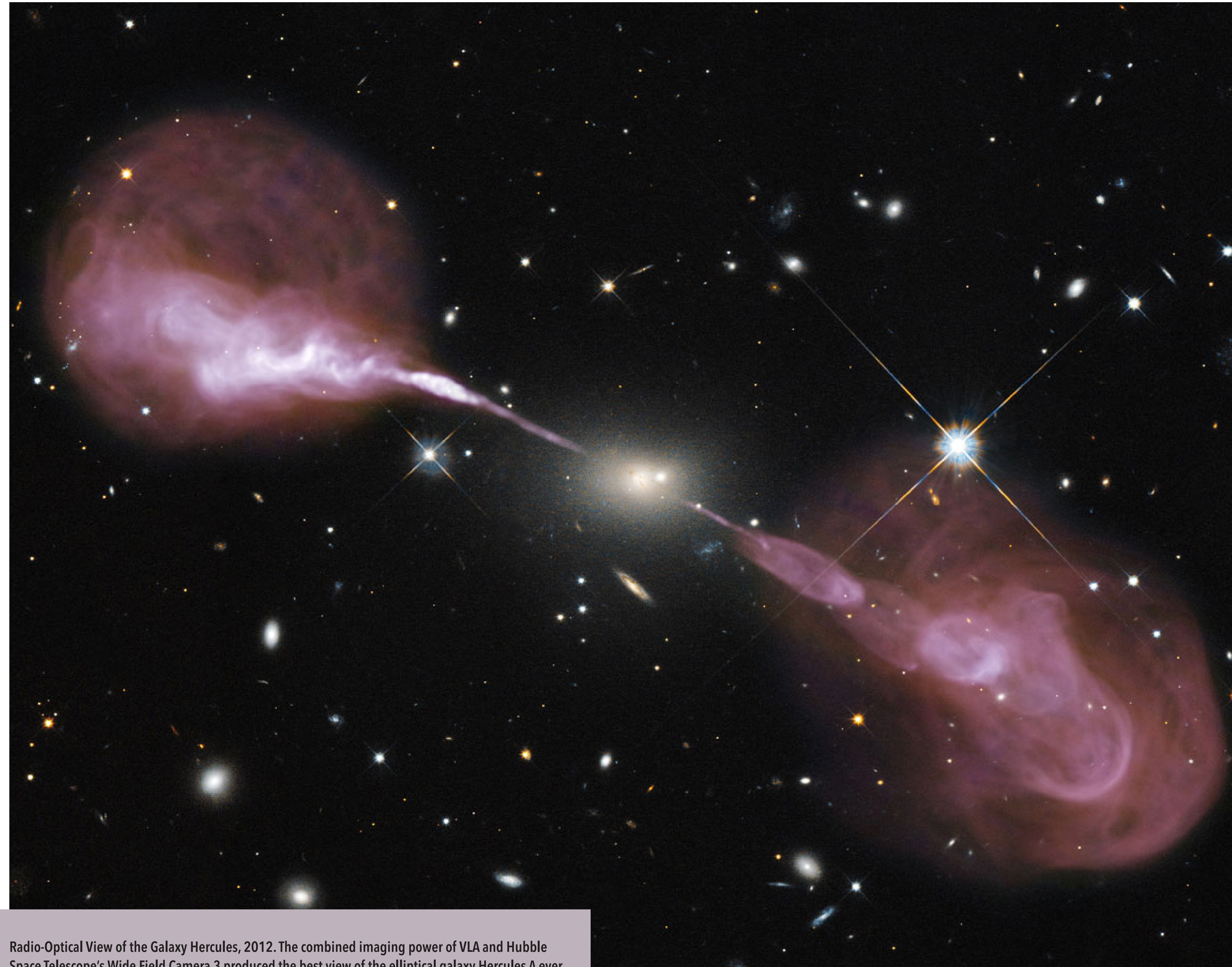

Radio-Optical View of the Galaxy Hercules, 2012. The combined imaging power of VLA and Hubble Space Telescope's Wide Field Camera 3 produced the best view of the elliptical galaxy Hercules A ever made. Some two billion light-years away, it appears quite ordinary when seen only in visible light. That is, until VLA revealed enormous jets powered by the gravitational energy of a super-massive black hole at its core.

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INTRODUCTION

The Karl G. Jansky Very Large Array (VLA) is the most productive, versatile, and widely-used radio telescope in the world. It is a component of the National Radio Astronomy Observatory (NRAO), a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

This centimeter-wavelength radio astronomy observatory comprises twenty-seven 25-meter radio telescopes deployed in a Y-shaped array and all the equipment, instrumentation, and computing power to function as an interferometer.

Astronomers using the VLA have made key observations of black holes and protoplanetary disks around young stars, discovered magnetic filaments and traced complex gas motions at the Milky Way's center, probed the Universe's cosmological parameters, and provided new knowledge about the physical mechanisms that produce radio emission.

Upgraded and Renamed

In 2011, a decade-long upgrade replaced the 1970s-era electronics with state-of-the-art equipment, expanding VLA's technical capacities by factors of as much as 8,000. It was renamed the Karl G. Jansky Very Large Array in honor of the American physicist and radio engineer considered one of the founding figures of radio astronomy. Karl G. Jansky first discovered radio waves emanating from the Milky Way in August 1931.

The VLA sits on the Plains of San Agustin, an ancient lakebed 7,000 feet high and surrounded by a natural fortress of rock that blocks radio pollution. This remote, flat stretch of desert in west-central New Mexico is the best location for collecting cosmic radio waves, which are billions of a billion times fainter than manmade radio waves.

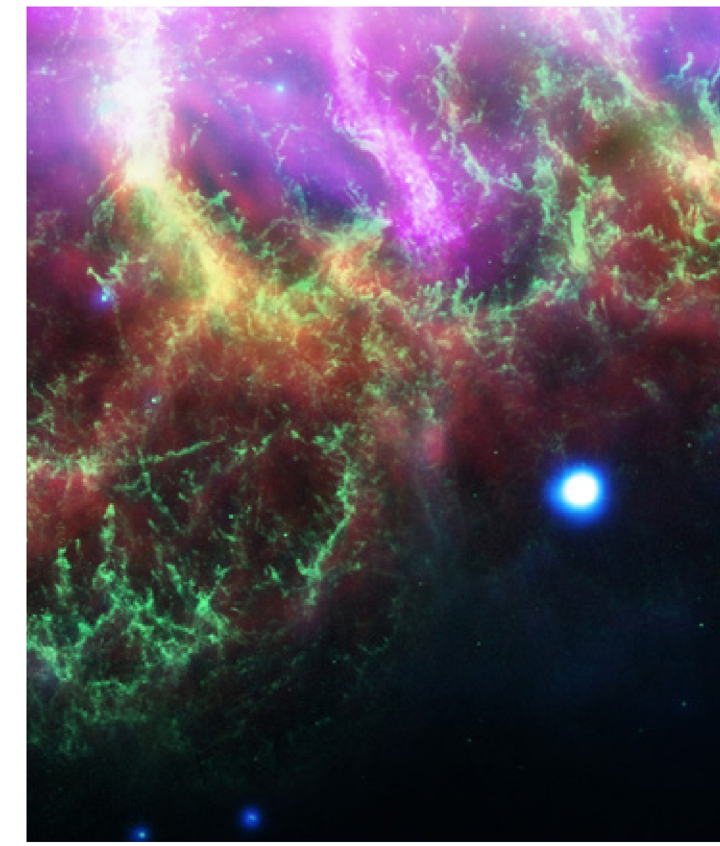
PROJECT HISTORY

On October 23, 2017, a six-hour interpretive planning workshop was held to discuss new exhibits at the VLA. Participants included several NRAO and VLA staff members, key volunteers, area educators, and community representatives. The workshop brainstormed interpretive goals, an overarching theme and subthemes, content suggestions, and exhibit ideas. The consultant then consolidated the group's ideas to create a guiding set of interpretive goals indemnifying what visitors should learn, feel, and do, as well as a suggested theme-subtheme structure to guide the next phase of planning.

NRAO contracted the exhibit planning and design firm Alchemy of Design, which partnered with BergerABAM to develop a concept design for a new visitor experience at the VLA. A project startup meeting held on March 5-6, 2018, clarified and further developed the ideas from the workshop. This revised draft builds on that work as well as comments received on the first submittal.

After the evaluation of the existing visitor center, it was decided to reconfigure and convert the existing cafeteria building into the visitor center. Test fits done by the design team proved that the functions held in the cafe can be successfully accommodated in the existing visitor center and that the cafeteria build can be available to house the new visitor center. To accomplish the goal of creating a well-designed center that offers an enhanced visitor's experience, the façade of the existing cafeteria would receive a facelift and an envelope upgrade to bring its energy performance up to current code. The interior would be designed so the layout and material selection work well with the interpretive elements of the project.

VLA discoveries have fundamentally changed what we know about space, from our home planet to the edges of the detectable universe. All of us–scientist and non-scientist alike–share in and benefit from the discovery process.



VLA in Array Configuration D (shortest). The VLA's 27 radio antennas are arranged in a reconfigurable Y-shaped array ranging from two-thirds of a mile to 23 miles long.

The VLA serves humanity's deep curiosity and drive to explore the universe and discover our relationship to it.

INTERPRETIVE APPROACH

The October 2017 workshop included a discussion of the five basic qualities of good interpretation:

1. It's purposeful, consciously serving the agency's mission while also meeting the interests of the visitor.
2. It's enjoyable, stimulating curiosity and emotions, and engaging the visitor in some way. Rather than overloading the visitor with too much information—a common error—it inspires a desire for further learning post-visit.
3. It's relevant, keeping the visitor's interests and day-to-day realities in mind by striving to be both personal and meaningful. This also means that interpretation for children should be approached differently than that for adults.
4. It's thematic, using the facts to convey a larger message that goes beyond the merely descriptive to connect to their deeper, intangible meanings.
5. It's organized, helping the visitor understand what to do and how to enjoy the site, ensuring that all messages and experiences work together to convey a unified whole, and addressing "Maslow's Hierarchy of Needs" to ensure maximum absorption and effectiveness.

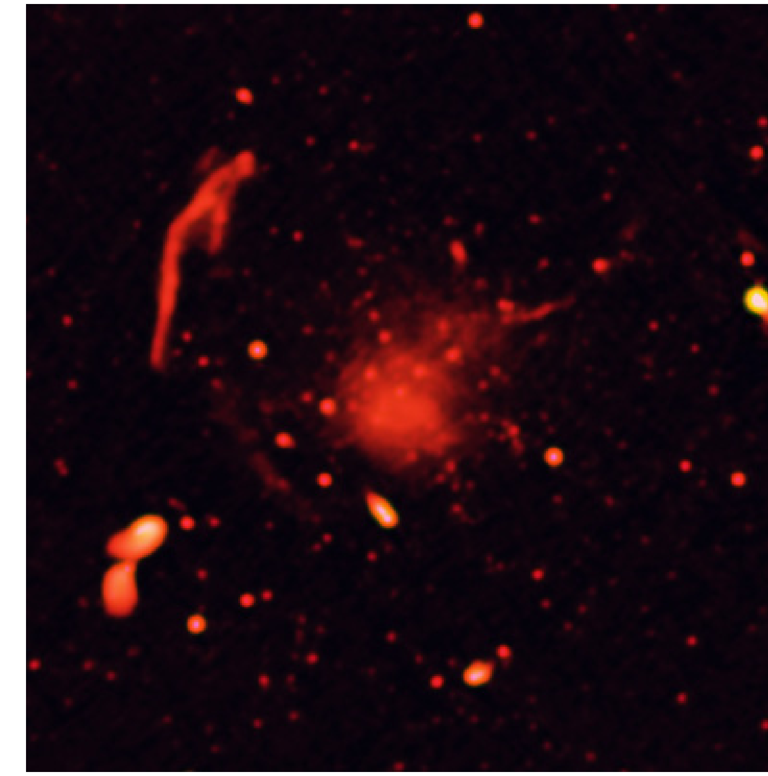
Tangible Resources & Intangible Meanings (Universal Concepts)

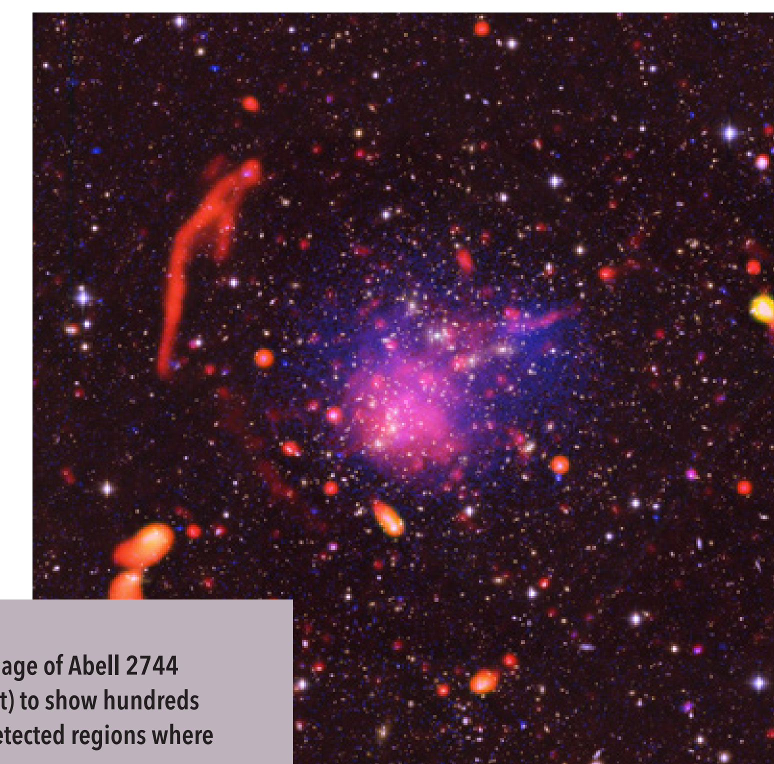
At the startup meeting, the team brainstormed a list of tangible resources and intangible meanings. Also known as Universal Concepts, these are the ideas that provide the greatest degree of relevance and meaning to the greatest number of people, and include ideas such as home, family, pride.

For the tangible resources of the VLA, the team identified the following intangible meanings: curiosity, discovery, exploration, thirst for knowledge, creativity, connectivity, advancement, improvement, effort, perseverance, hard work, pride, passion, dedication, innovation, efficiency, and belief in science and the scientific process.

TARGET AUDIENCES

The workshop identified target audiences that included both travelers as well as local residents, such as area schoolchildren, educators, and adult citizens.





Shocking Results of Galaxy-Cluster Collisions. This composite image of Abell 2744 region combines data from radio, X-Ray, and optical (visible light) to show hundreds of galaxies colliding. VLA observations revealed previously undetected regions where shocks accelerated subatomic particles, causing radio emission.

INTERPRETIVE GOALS

The VLA is a marvel of technology, working alongside the world's greatest scientific instruments on Earth and in space.

Interpretation is not the same as information. Instead, interpretation is a mission-driven communication process that provokes interest, engages the user in the story, relates to the user's everyday life and values, and reveals hidden meanings and relationships. Interpretation should happen at the intersection of three realms: The stories arising from the resource, visitors' intrinsic interests, and the mission and goals of the organization. Anything else will either be lost on the visitor, or wasted effort on the part of the organization. The following goals were identified at the workshop:

1. Interpretation will make information understandable and relevant for non-scientists as well as scientists.
    a. Non-scientist visitors will understand in general terms the basics of radio astronomy and the VLA—and feel happily surprised that they can.
    b. Scientists will appreciate the clarity of the message, without over-simplification to the point of introducing inaccuracies.
2. People of diverse backgrounds will feel welcome and actively included.
    a. Provide a venue for diverse cultural voices and include women and persons of color.
    b. Encourage Navajo and Puebloans to share their stories.
3. Educators will value and use the VLA as a resource.
4. Artists will feel invited to access and reinterpret for wider audiences.
5. Visitors and residents will understand how natural conditions here support the VLA, and will feel inspired to help maintain those conditions.
6. Visitors will understand why the VLA exists, and feel the program is useful, relevant and worth supporting.
    a. People will understand how the VLA fits into the bigger picture of astronomy and human discovery.
    b. Visitors will feel they are an integral part of the universe, not separate from it.
    c. Local residents and visitors will feel pride and ownership in the VLA's role in unlocking the secrets of the universe.
    d. Visitors and locals will understand in general terms the politics and policies that impact VLA, and will become supporters and advocates.
    e. Visitors will see ways they can contribute to the VLA—whether by donating, volunteering, encouraging others to visit, or as voting citizens.
    f. Visitors and locals will see us as a worthy resource and feel VLA is a good use of tax dollars.
7. Visitors will be inspired to learn more.
    a. People will be inspired to become life-long learners and learn of ways to continue their explorations back home.
    b. Visitors of all ages will have kinesthetic experiences that help them learn and remember and return to participate in future programs.
    c. Young people will see career opportunities in our stories and programs: "I can do this—I can be a part of science."
8. Visitors will share their positive experiences with others back home.

EXTERIOR ARCHITECTURE

The exterior scope of the project will focus on a major aesthetical upgrade and functional improvement. This will entail bringing the envelope's energy performance to current code by providing continuous insulation over the existing slump block wall system and using a code compliant storefront system. Durable metal cladding with finishes that complement the arid and desert environment will be used to create the exterior aesthetic of the visitor center.

Site Design

The master plan reorganizes site circulation to reduce pedestrian-vehicle conflicts, provides additional outdoor interpretive opportunities, and reduces potential radio frequency interference impacts from visitor. The radio wave form is expressed in a meandering pathway that leads guest from the parking area through outdoor interpretive elements and a native Galaxy Garden to the new visitor center. Drought-tolerant indigenous plantings, shade structures, benches, picnic tables and a new comfort station enhance the visitor experience. Viewpoints and an outdoor classroom provide opportunities for learning and discovery.

Radio Frequency Inference Mitigation

Recognizing that radio frequency interference (RFI) negatively affects sensitive instruments and degrades the quality of data received at the VLA, the master plan seeks to mitigate potential impacts from the building improvements and visitors. Visitor parking will be located a minimum 500 meters from VLA antennas to help mitigate RFI emitting from vehicle communications and entertainment equipment. The RFI Gateway and enhanced signage will remind visitors to power off cell phones, tablets, and other connected devices.

Aerial view of site and visitor center.

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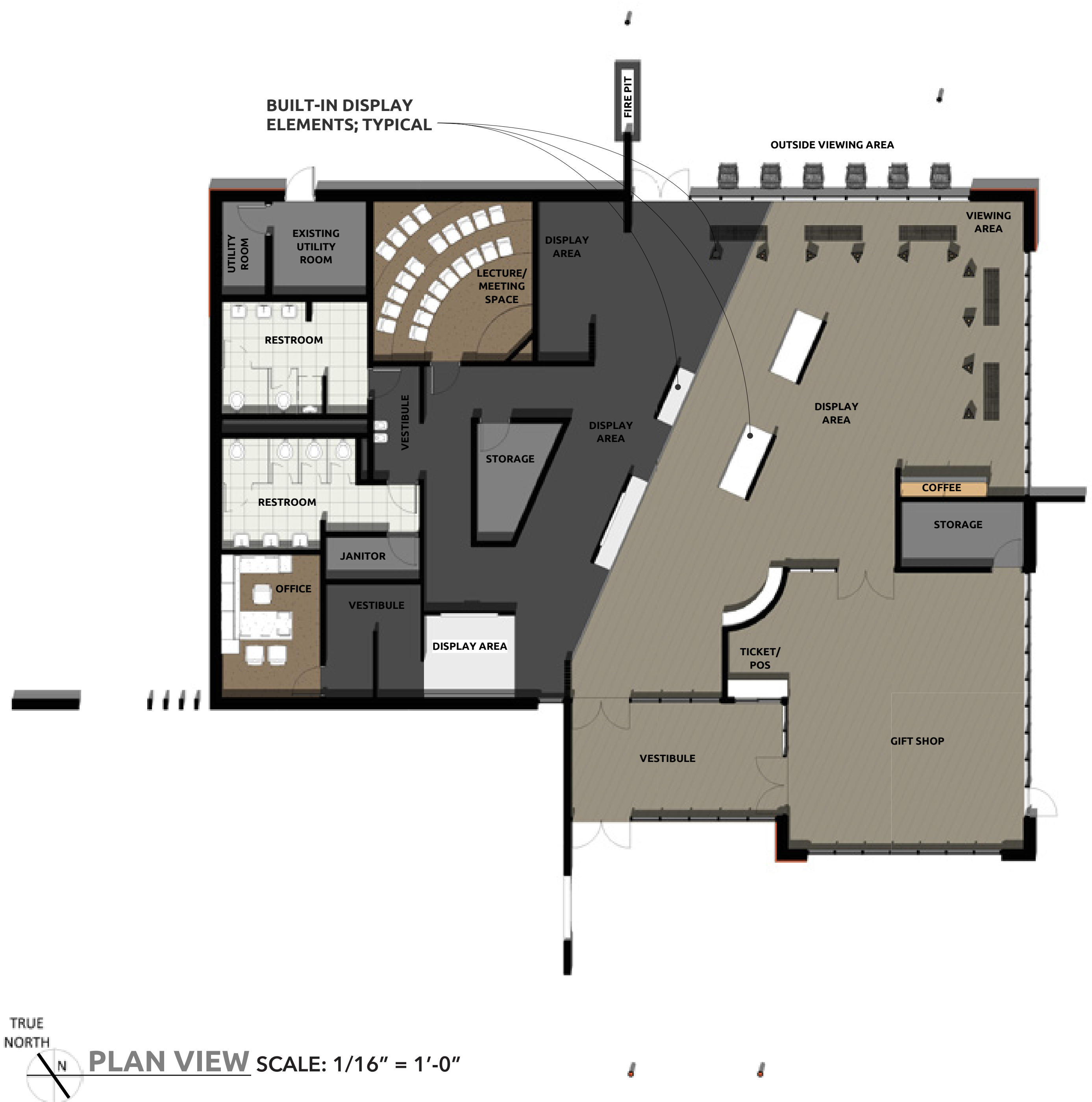
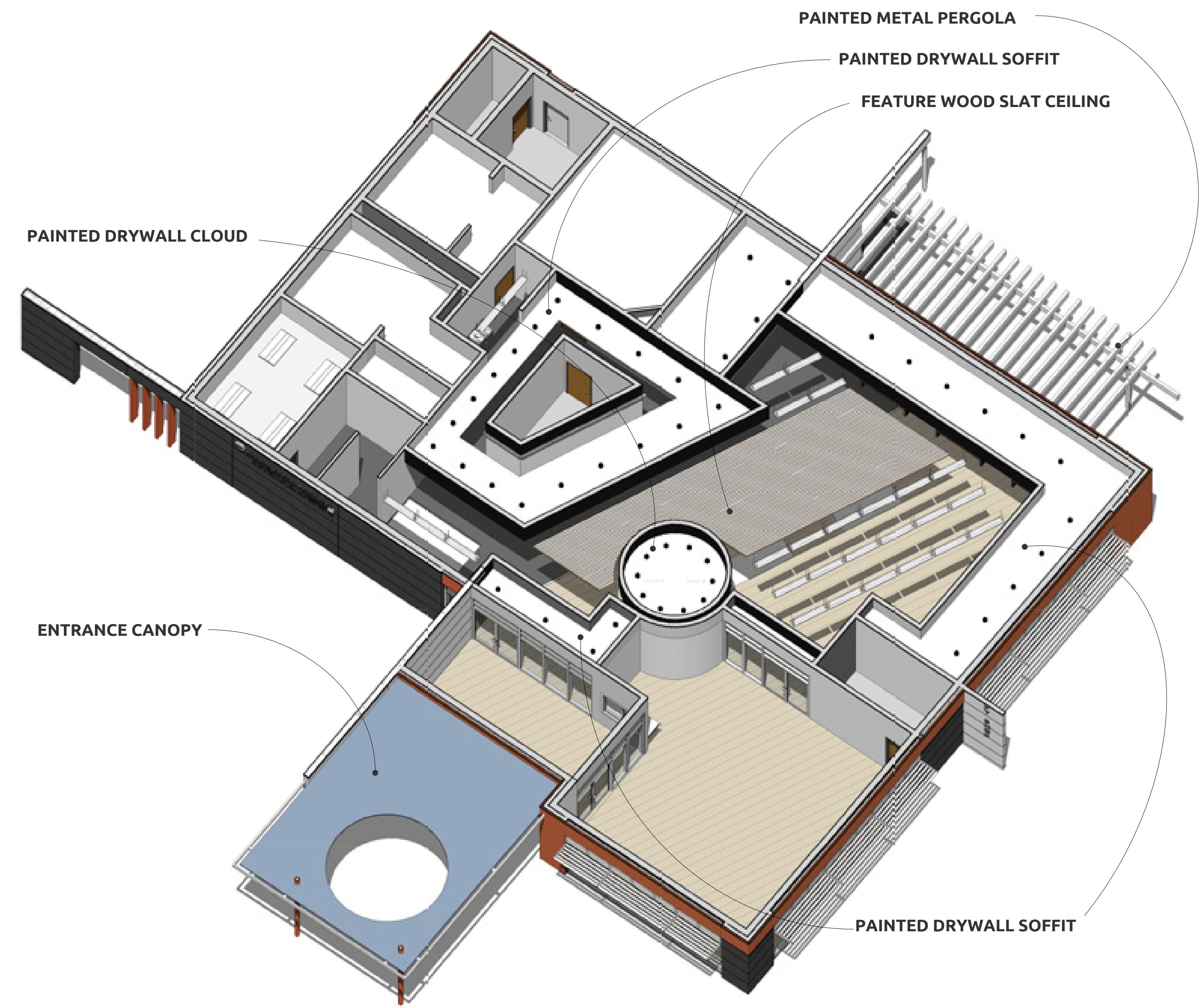
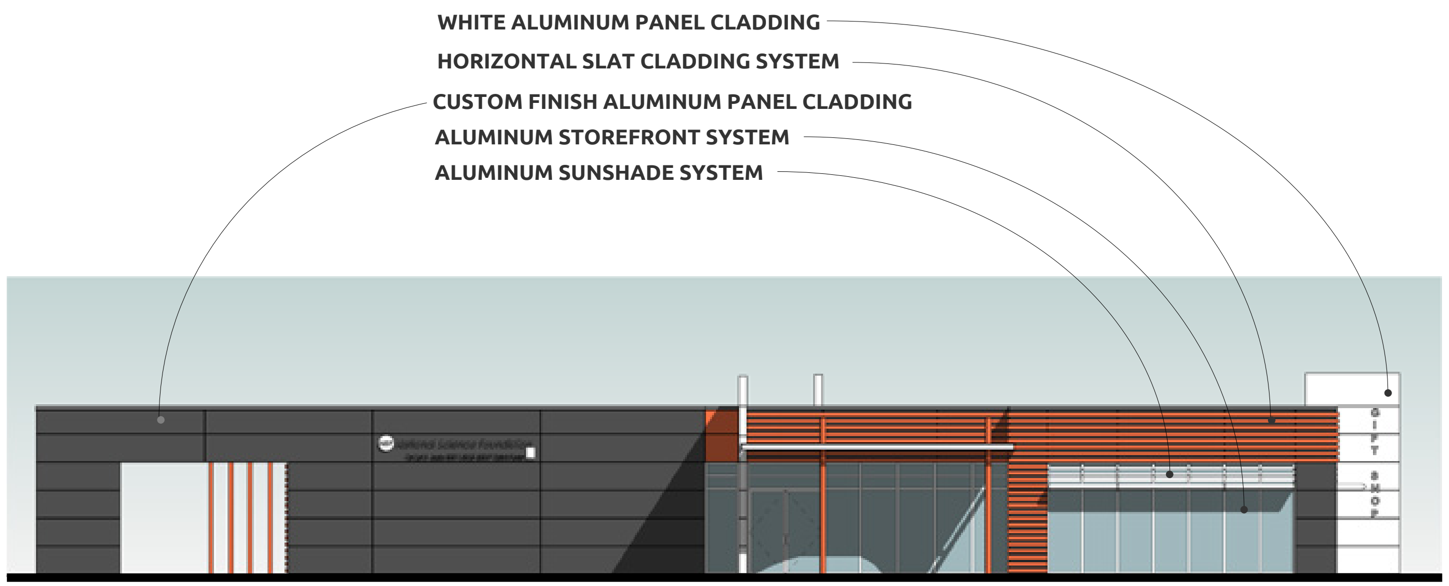


PLAN VIEW SCALE: 1/16" = 1'-0"

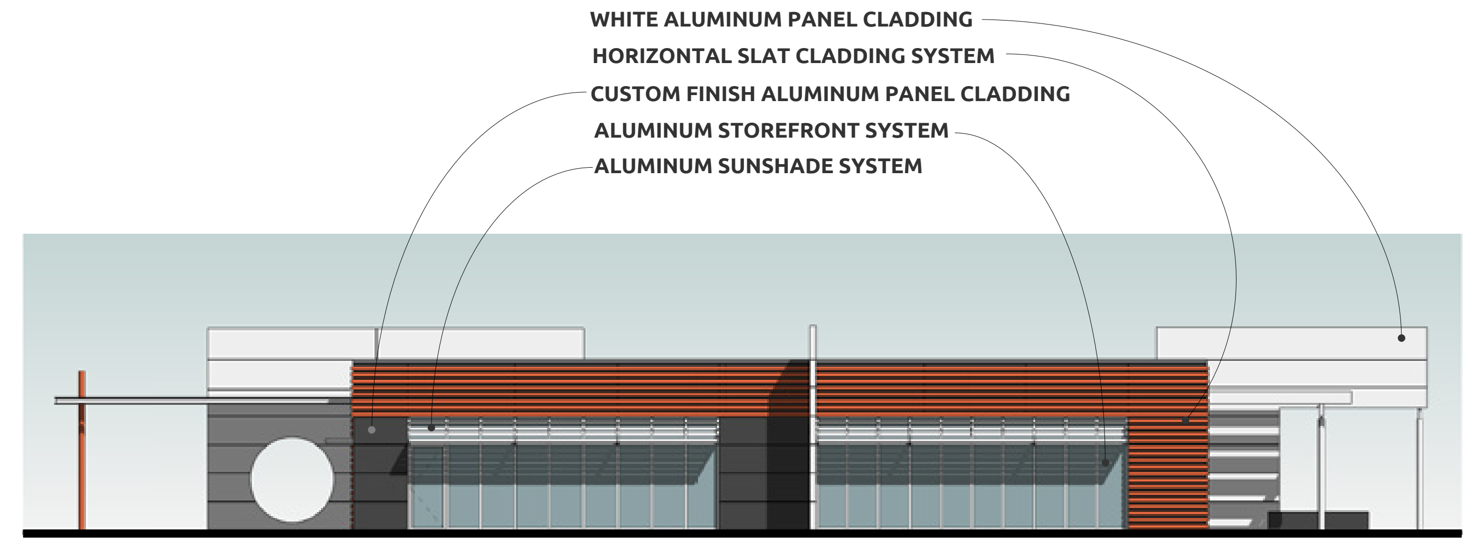


AXONOMETRIC VIEW SCALE: 1/16" = 1'-0"

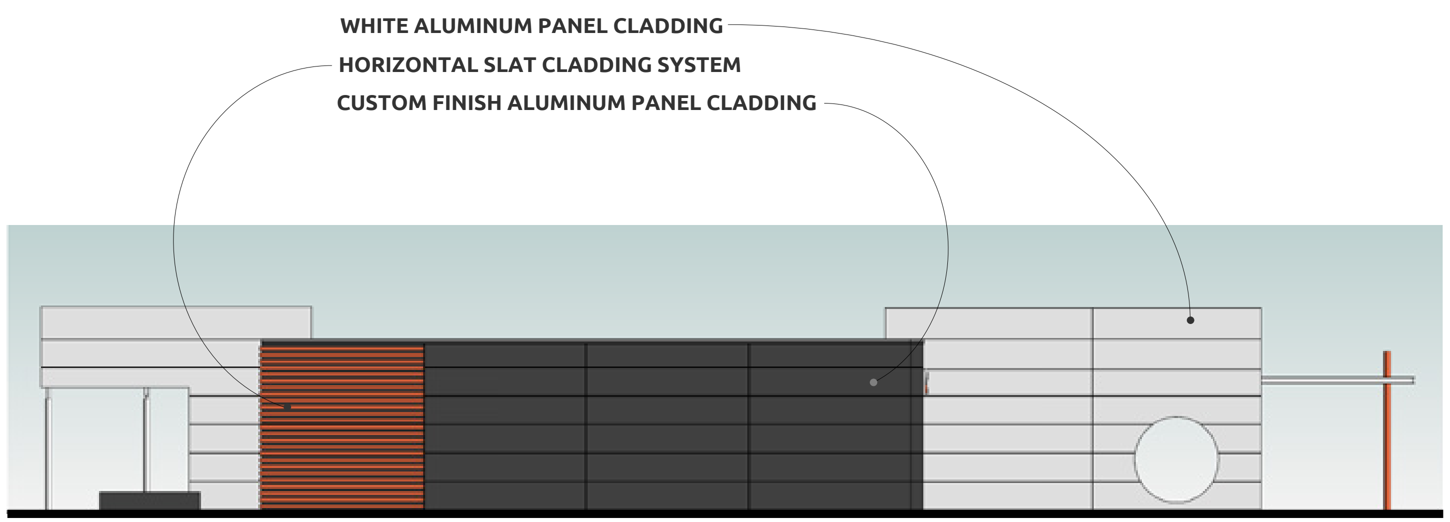
Layout



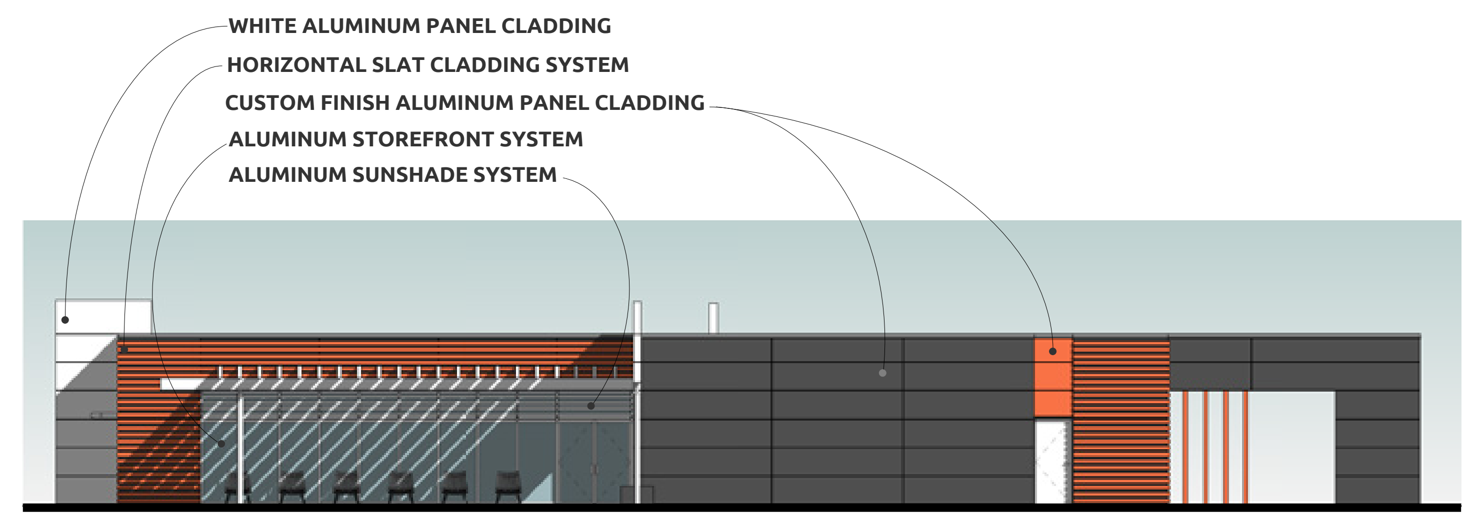
SOUTHWEST ELEVATION SCALE: 1/16" = 1'-0"



SOUTHEAST ELEVATION SCALE: 1/16" = 1'-0"

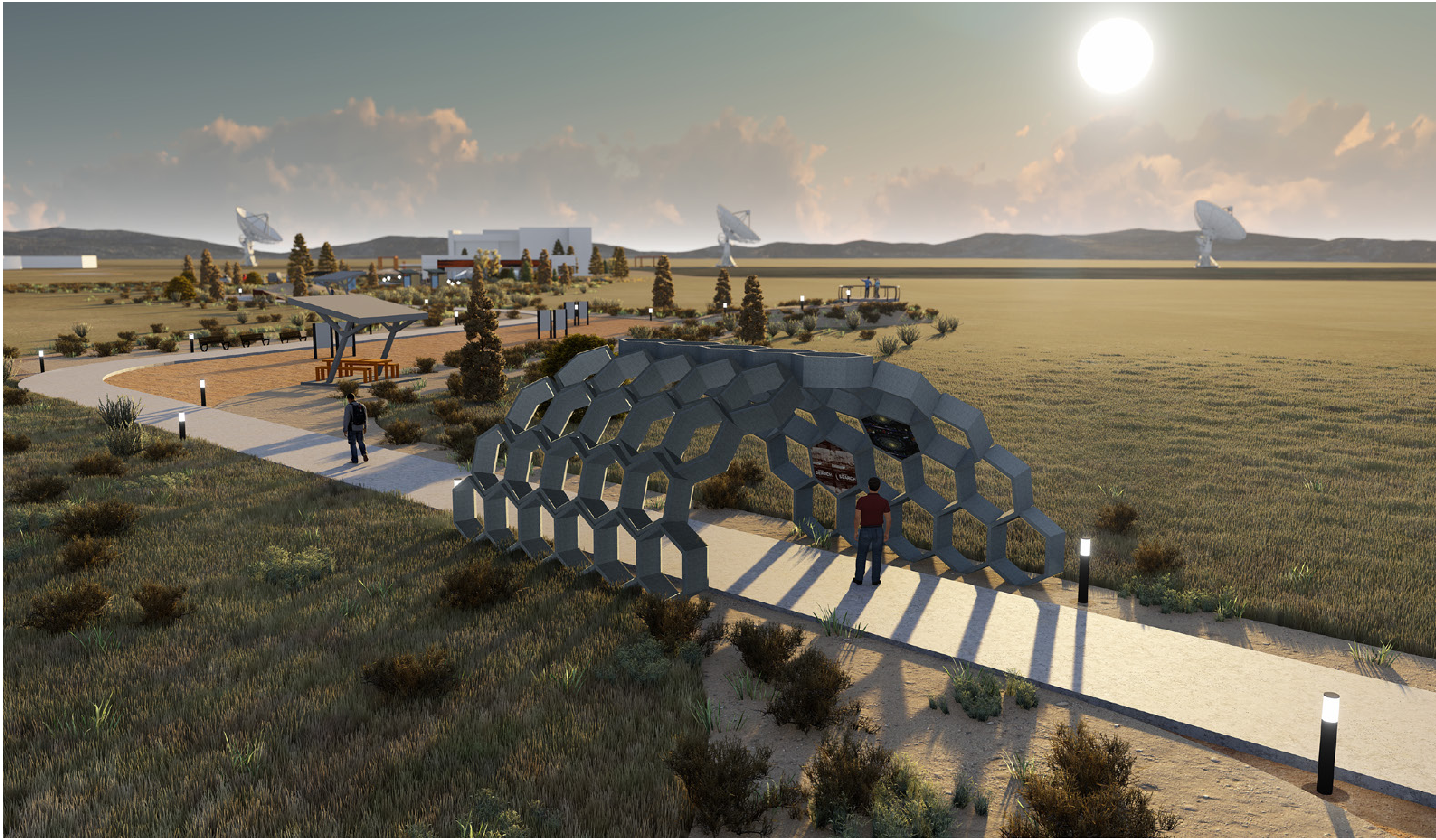


NORTHWEST ELEVATION SCALE: 1/16" = 1'-0"

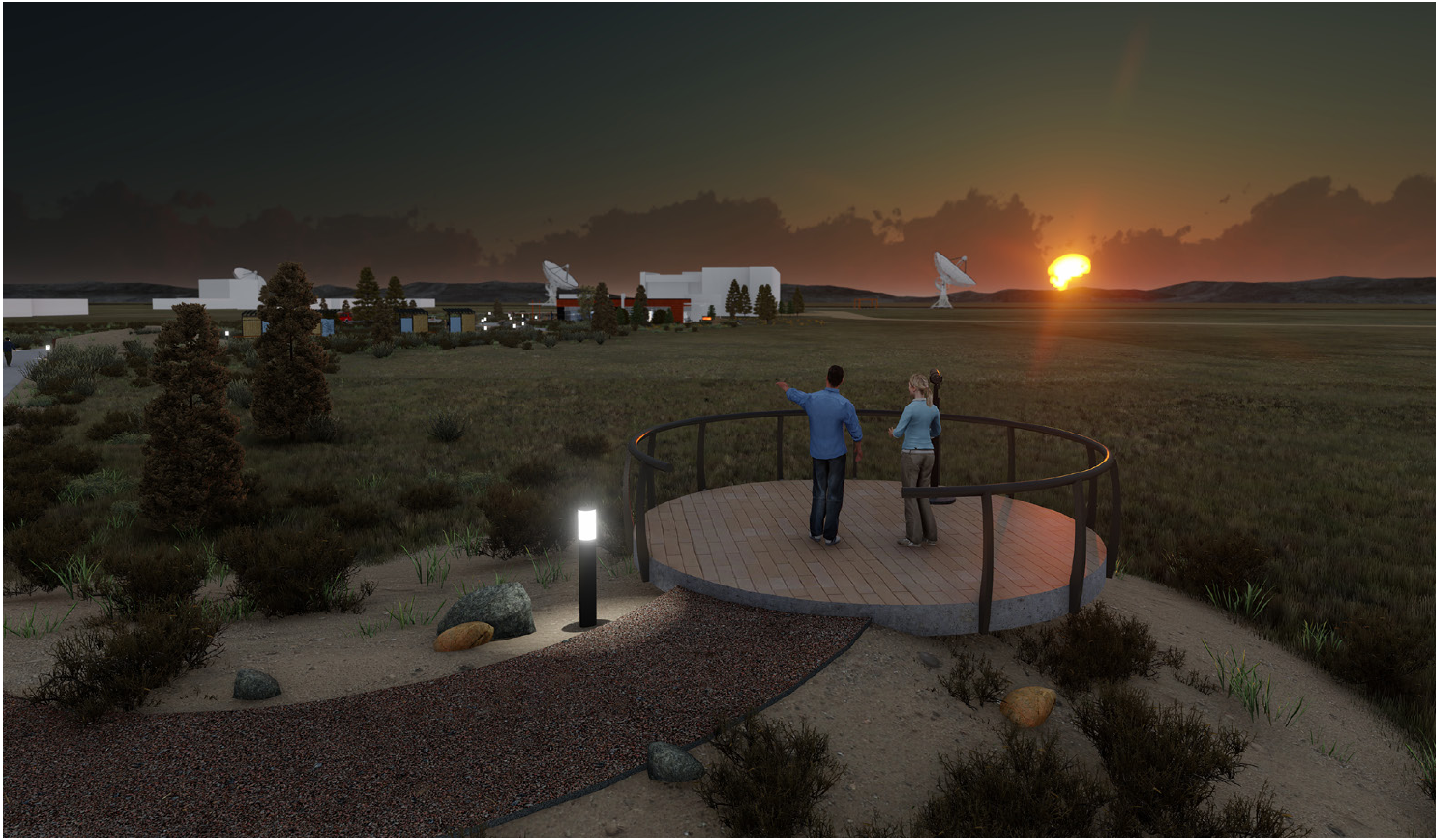


NORTHEAST ELEVATION SCALE: 1/16" = 1'-0"

Visitor parking area. Visitor parking will be relocated to a minimum 500 meters from VLA antennas to help mitigate RFI emitting from vehicle communications and entertainment equipment.



RFI Gateway and Discovery Walk. A meandering pathway suggestive of a radio wave leads guests from the parking area through outdoor interpretive elements and a native Galaxy Garden to the new visitor center. Enhanced signage will remind visitors to power off cell phones, tablets, and other connected devices.



VLA Viewpoint. Viewpoints encourage visitors to pause to take in the view and provide opportunities for learning and discovery.

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Native Galaxy Garden and shaded benches. Drought-tolerant indigenous plantings, shade structures, benches, picnic tables and a new comfort station enhance the visitor experience.

View of the south corner of the Visitor Center–Main Entrance. The exterior scope of the project will focus on a major aesthetical upgrade and functional improvement. This will entail bringing the envelope's energy performance to current code by providing continuous insulation over the existing slump block wall system and using a code compliant storefront system.

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View of the west corner of the Visitor Center. Durable metal cladding with finishes that complement the arid and desert environment will be used to create the exterior aesthetic of the visitor center.

View of the north corner of the Visitor Center. Exterior improvements will include new windows and a new back patio with seating to encourage visitors to linger there and enjoy the view.

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View of the east corner of the Visitor Center. Outdoor elements include a new fire pit and a wall that helps define the space.

INTERIOR & EXHIBITS

Interior Architecture

The interior space of the visitor center is laid out to create a visual connection to the outside. In addition, the space is divided into dark and light areas to evoke a feeling of juxtaposition of mystery and enlightenment. Wood accents are used throughout to bring in some warmth and add some natural texture to the inside.

Radio Frequency Interference Mitigation

Monitors, projectors, and displays will be shielded to block RFI and low noise lighting, network, and mechanical equipment will be specified during building renovations.

Exhibits

The exhibit design works in harmony with the architecture to guide visitors through a thematic exploration of the VLA's mission and discoveries. Large, iconic imagery and dimensional elements capture their attention and hold their interest, connecting them to deeper, intangible meanings behind the science and engineering at the VLA. The shapes and materials of the design helps support the mechanical and engineering principles that make the amazing science conducted at the VLA a reality.

The RFI interactive exhibit Mixed Signals helps visitors understand how electronic devices, especially cell phones, WiFi, and microwaves, interfere with the science conducted at the VLA. By pulling a panel that shields a smart phone from an RFI detector, visitors see how much interference this simple, everyday device creates.

Visitors of all ages will have kinesthetic experiences that help them learn and remember and return to participate in future programs.

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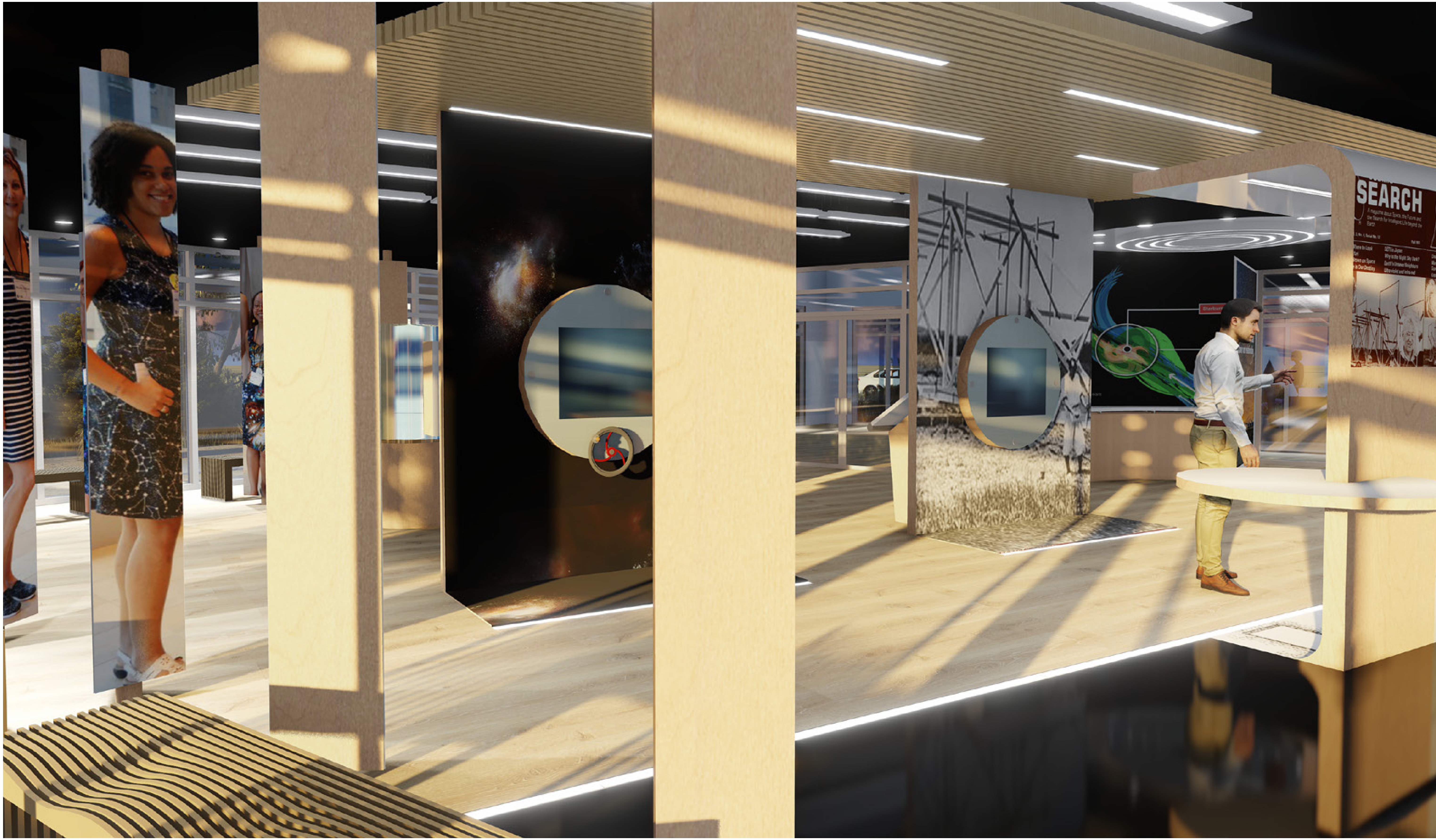
View of "Dark Area" looking north. At Revealing the Unseen, visitors are surprised to learn that visible light only provides a limited view of the universe. The white-on-white dimensional title of the exhibit is a subtle nod to this principle. Visitors explore dimensional and kinesthetic elements to reveal information about the electromagnetic spectrum and how these discoveries led to many of the technologies we use every day.

One of the first exhibits, Ancient Wonderings, sets the stage with a brief history of astronomy, starting with the first known record of an eclipse by Chinese astronomers to 18th-century Persian astrolabes and Edmond Halley's predictions of the return of the comet that now bears his name.

"Light Area" looking south. Artifacts, imagery and interactives interpret the basics of radio astronomy and the VLA in ways that are understandable and relevant for non-scientists as well as scientists.



Video Display Area. Exhibits with electronic elements will be clustered together where possible to make RFI shielding more practical. Monitors, projectors, and displays will be shielded to block RFI and low noise lighting, network, and mechanical equipment will be specified for building renovations and exhibit areas.

"Dark" Display Area looking south. At the Jansky's Merry-Go-Round: The First Radio Telescope exhibit (left), visitors learn the early history of radio astronomy against the large backdrop of a historic photo of Jansky's merry-go-round, the first radio antenna used to identify an astronomical radio source.

Coffee area. As visitors near the end of the exhibit experience, they find a coffee area that encourages them to linger in the space and enjoy the view out the windows. At he final exhibit, ngVLA, visitors learn about future plans for the VLA.

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The Control Room exhibit is located in a shielded area on the back side of the theater. Staged to look like the actual control room, visitors learn how array operators monitor the antennas and how the powerful WIDAR Supercomputer correlates the data.

CONTENT MATRIX

Themes

OVERARCHING THEME: The VLA serves humanity's deep curiosity and drive to explore the universe and discover our relationship to it.

Theme 1: The VLA sees with different eyes to reveal the unseen.

Theme 2: VLA discoveries have fundamentally changed what we know about space—from our home planet to the edges of the detectable universe.

Theme 3: The VLA is a marvel of technology, working alongside the world's greatest scientific instruments on Earth and in space.

Theme 4: All of us—scientist and non-scientist alike—share in and benefit from the discovery process.

APPROACH & ENTRY: TURN OFF / TUNE IN	CONTENT
As visitors approach and enter the building, they are greeted with messaging that reminds them to turn off their personal electronic devices.	▸ Please make sure all electronic devices (cell phones, tablets, or anything else with an "On/Off" switch) are in airplane mode and powered off. Please turn all WiFi and Bluetooth devices off as well. ▸ You may briefly turn on electronic devices to take photographs while in airplane mode, but please power your device off again.

THEATER	CONTENT
Visitors watch the orientation video and assemble for tours in the theater, located in the back left corner of the building past the bathrooms.	▸ Large, stunning images of some of the VLA's famous images decorate the theater.

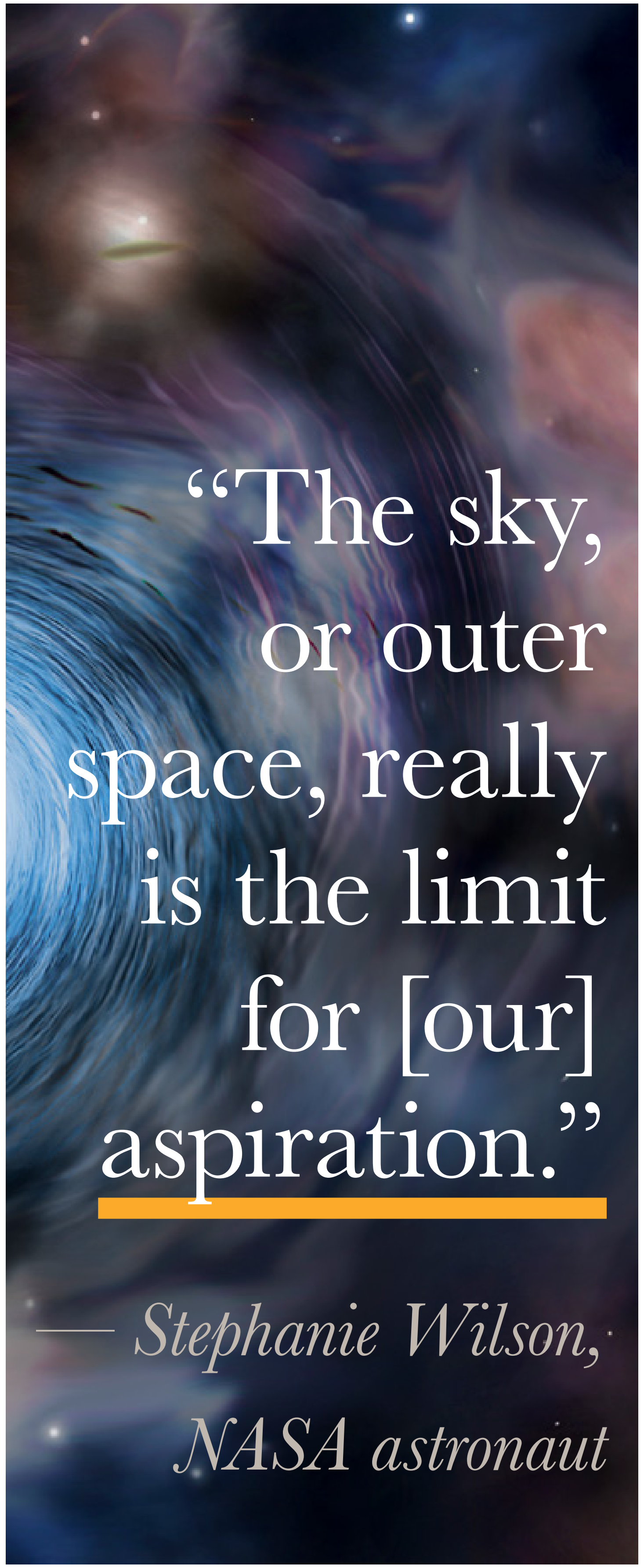
INTRODUCTION: THE WHY	CONTENT
Once inside the exhibit area, visitors are greeted with an introduction that includes the main theme writ large against a stunning backdrop of the array. Brief text provides an overview of the VLA's significance and invites visitors on a path of inquiry to discover more.	▸ The Very Large Array (VLA) is the most advanced radio telescope array on Earth. Operating at radio frequencies, the VLA observes the sky 24 hours a day, 362 days a year, in all but the most severe weather conditions. Why Astronomy? ▸ Answers humanity's biggest questions, including our place in it. ▸ Continues to revolutionize our thinking on a worldwide scale. ▸ Drives technological advancements essential to modern life, including personal computers, communication satellites, mobile phones, Global Positioning Systems (GPS), solar panels, Magnetic Resonance Imaging (MRI) scanners, and more. ▸ Inspires artistic expression.

INTRODUCTION: THE WHY	CONTENT (CONTINUED)
	NRAO ▸ The VLA is part of the National Radio Astronomy Observatory (NRAO), a facility of the National Science Foundation. ▸ NRAO was founded in 1956, to provide state-of-the-art radio telescope facilities for use by the international scientific community. Open Skies Policy ▸ NRAO telescopes are open to all astronomers regardless of institutional or national affiliation. Observing time is available on a competitive basis.

MIXED SIGNALS: RFI INTERACTIVE	CONTENT
The RFI interactive exhibit MIXED SIGNALS helps visitors understand how electronic devices, especially cell phones, WiFi, and microwaves, interfere with the work at the VLA. By pulling a panel that shields a smart phone from an RFI detector, visitors see how much interference this simple, everyday device creates.	▸ We ask visitors to shut off electronic devices while at the VLA to keep them from interfering with these weak signals coming from outer space. ▸ These faraway signals are extremely weak – millions (or billions) of times weaker than the signals used by today's communication systems. ▸ Because these cosmic radio sources are so weak, they are easily masked by man-made interference, which can also contaminate the data collected by radio telescopes. » *A cellular telephone on the Moon could produce a signal much stronger than the ones radio astronomers are searching for.* » *Active transmit devices–such as cell phones, microwave ovens, WiFi, and wireless driver assist technology such as backup cameras common on today's cars–are the biggest source of RFI and cause the most problems at the VLA.* » *Powered electronics also cause some RFI issues, although not as much as active transmit devices. So even if your cell phone is in airplane mode with the WiFi turned off, it could still be interfering* » *with data collection.*

"An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer."

—Max Planck



ANCIENT WONDERINGS	CONTENT
ANCIENT WONDERINGS sets the stage for the story of the VLA by highlighting the history of humanity's deep curiosity about the universe. This exhibit provides the background information needed to understand the significance of the VLA's discoveries and helps visitors understand how the VLA fits into the bigger picture of astronomy and human discovery. Stunning images of historical figures and ancient sky maps draw visitors to a brief timeline of astronomical discoveries from ancient times up to the 1800s. This exhibit introduces the idea of how humans have always looked to the sky with wonder, and their early attempts to describe and explain what they can observe. Here visitors learn that discoveries build on one another in an endless process inquiry, observation, and experimentation. Artistic impressions of astrological phenomenon, from Bronze Age artifacts such as the ca. 1600 BC Nebra sky disk and Medieval illustrated manuscripts to Lieve Verschuier's, 1680 painting, Comments Over Rotterdam, and Donato Creti's, 1711 Astronomical observations paintings, are included in the timeline.	‣ People have always marveled at the constellations. Astronomy is one of our oldest sciences, and is part of every culture's history and roots, including origin stories. ‣ In the past, astronomy has been used to measure time, mark the seasons, and navigate the vast oceans. Timeline Highlights: ‣ 2136 BC: Chinese astronomers made the first known record of an eclipse. ‣ 750 BC: Babylonian astronomers created the first almanacs with tables of the movements of the Sun, Moon, and planets. ‣ 585 BC: Greek philosopher Thales predicts a solar eclipse. ‣ 388 BC: Greek philosopher Plato promotes the idea that the Sun, Moon, and planets move around Earth in perfect circles. ‣ 240 BC: Chinese astronomers made the first known recorded sighting of Halley's Comet. ‣ 4th Century BC: Chinese astronomers Gan De and Shi Shen were the first in history known by name (after the Babylonians) to have compiled a star catalogue, identifying 809 stars in 122 constellations. ‣ 140 AD: Ptolemy publishes his star catalogue of 48 constellations and promotes a geocentric view of the universe. ‣ ~500 AD: Indian mathematician and astronomer Aryabhatta proposed that the that Earth travels around the Sun. ‣ ~820 AD: Persian mathematician and astronomer Muhammad ibn Mūsā al-Khwārizmī invented algebra and calculated the positions of the Sun, Moon, and planets. ‣ ~890 AD: Persian mathematician and astronomer Abu Mahmood al-Khujandi helped build a large observatory near the city of Ray (near modern-day Tehran) in Iran. ‣ ~AD 906: Pyramid of El Castillo, a Mayan observatory, was built in Chichén Itzá on the Yucatán Peninsula in modern-day Mexico. ‣ ~1000 AD: Ancient Pueblo people at Chaco Canyon construct buildings aligned to capture the solar and lunar cycles. ‣ 1054: Chinese astronomers observed the supernova that created the Crab Nebula, which they recorded as a "guest star." ‣ 1436 AD: Ming Dynasty ruler Zhengtong had an observatory built in Beijing. ‣ 1543: Nicolaus Copernicus publishes his theory that Earth travels around the Sun. ‣ 1609: Johannes Kepler publishes his three laws of planetary motion, replacing Plato's idea of circular orbits with elliptical ones. ‣ 1610: Galileo Galilei publishes his observations with the telescope he built, supporting Copernicus' theory that Earth travels around the Sun. ‣ 1687: Isaac Newton publishes his theory of gravitation and laws of motion, which explains Kepler's laws of planetary motion. ‣ 1705: Edmond Halley calculates that the comets recorded at 76-year intervals from 1456 to 1682 are all the same one. He predicts it will return again in 1758.

REVEALING THE UNSEEN: INTERACTIVE EM SPECTRUM & TIMELINE	CONTENT
At REVEALING THE UNSEEN, a large graphic of the electromagnetic spectrum vividly demonstrates that visible light is only a small fraction of a range of frequencies that make up the electromagnetic spectrum. Here visitors are startled to learn that visible light only provides a limited view of the universe. This exhibit provides visitors with a kinesthetic experience that reinforces how much of the EM spectrum is outside the range of visible light. Visitors are encouraged to turn a dial that shows the relationship between wavelength and frequency and how lower frequencies have longer wavelengths. This area also includes a time timeline that picks up where Ancient Wonderings left off, with Sir Frederick William Herschel discovery of infrared light in 1800. This timeline focuses mostly on the discoveries and innovations that led to radio astronomy. Visitors pull drawers to reveal more information about the electromagnetic spectrum, including major discoveries and their importance to astronomy, as well as how these discoveries led to many of the technologies we use every day. Artistic impressions of astrological phenomenon from the 1800s are included in this timeline, picking up where the timeline in Ancient Wonderings left off. This includes Vincent Van Gogh's 1889 painting, *The Starry Night*.	▸ The human eye can only see a tiny band of the electromagnetic spectrum. Visible light shows us just a fraction of the information available—giving us only a limited view of the universe. ▸ VLA sees with different eyes to reveal the unseen. » *Radio telescopes allow us to expand our range of vision beyond the visible spectrum and view cosmic objects at a level of detail not possible with optical telescopes.* » *The VLA observes radio waves, a kind of light that, though invisible to the human eye, is the most widespread type of light given off in the Universe.* ▸ VLA is an extremely sensitive radio receiving system, collecting faint emissions from faraway astronomical objects at unimaginably great distances. These weak signals can tell big stories. ▸ Because of its ability to detect very weak signals, the VLA is able to: » *Receive the signals of the Voyager spacecraft as it passed by the distant planet Neptune in 1989.* » *Receive the signals of the Galileo probe as it descended into the atmosphere of Jupiter in 1995.* Timeline Highlights ▸ 1800: Sir Frederick William Herschel discovers infrared light. ▸ 1801: Johann Wilhelm Ritter discovers UV radiation. ▸ 1864: James Clerk Maxwell predicts radio waves from equations. ▸ 1888: Heinrich Hertz 1st to demonstrate microwaves. ▸ 1894: Jagdish Chandra Bose publicly demonstrates microwaves. ▸ 1895: Wilhelm Röntgen discovers X-rays. ▸ 1900: Paul Villard discovers gamma radiation. VLA Today ▸ The telescope can currently observe 10 different frequency bands ranging from approximately 74 MHz (4-band) all the way up to 50 GHz (Q-band), ▸ In a given day, it may observe astronomical objects such as supernovae, hydrogen gas clouds, gamma ray bursts, active galactic nuclei (AGNs), and occasionally even the sun or planets.

JANSKY'S MERRY-GO-ROUND: THE FIRST RADIO TELESCOPE	CONTENT
Visitors learn the early history of radio astronomy against the large backdrop of a historic photo of Jansky's merry-go-round, the first radio antenna used to identify an astronomical radio source. Other historic photos briefly chronicle the founding of the National Radio Astronomy Observatory in 1956 and the development of the Green Bank Interferometer, a four-telescope array that served as a test run for the VLA, which began construction in 1973.	▸ Karl Guthe Jansky is considered one of the founding figures of radio astronomy. In 1931 he was first to discover radio waves emanating from the Milky Way. He called it "star noise." ▸ A physicist and radio engineer with Bell Telephone Laboratories, Jansky was assigned the job of identifying sources of static that might interfere with radio telephone service. ▸ Jansky built an antenna that was an array of dipoles and reflectors designed to receive radio waves at a frequency of 20.5 MHz (wavelength about 14.6 meters). Mounted on a turntable on a set of four Ford Model-T tires, it could be rotated in any direction, earning it the name Jansky's merry-go-round.

THEATER	CONTENT
The theater is strategically located in the back corner between the exhibits that set the historical and scientific context and those that explore the VLA itself. Here visitors can watch an orientation video, assemble for tours and visit revolving art exhibits.	▸ Large, stunning images of some of the VLA's famous images decorate the theater, which also functions as a changing art gallery space for a variety of art installations, from school and community projects to professional art.

EXPLORE THE VLA: ORIGINS	CONTENT
Several distinct but related exhibits work together as one larger Explore the VLA exhibit area dedicated to the history and technology of the VLA. The first exhibit, EXPLORE THE VLA: ORIGINS, sets the VLA in time and place against a stunning mural of one of the VLA's signature images. Here visitors learn the basics about the array and its location, including how the natural conditions here support the VLA's important work and the things they can do to help maintain those conditions. From there, visitors continue on to explore computer interactives in the Control Room exhibit, interact with a large diagram of an antenna, and learn about major VLA discoveries.	‣ In 1973, VLA construction began on the Plains of San Agustin, a remote, flat stretch of desert in New Mexico. ‣ At over 7,000-feet elevation, this ancient lakebed provides the space needed to lay 40 miles of double-track rails required to extend the VLA's Y-shape to give us its highest resolution capability. ‣ Ringed by a natural fortress of rock that keeps out any traveling radio pollution from cities even hundreds of miles away, this was the best location for collecting the most cosmic radio waves, which are billions of a billion times fainter than manmade radio waves.

EXPLORE THE VLA: IT TAKES A VILLAGE	CONTENT
At the IT TAKES A VILLAGE exhibit, visitors meet some of the many people are needed to run the VLA and learn about the specialized knowledge, skills, and experience needed to do their jobs. Visitors are prompted to look for people of the VLA throughout the remaining Explore the VLA exhibits, which highlight some of the specialized jobs associated with each topic. For example, they learn more about antenna mechanics in the nearby Explore a VLA Antenna exhibit.	‣ The VLA requires a large, technically-savvy group of people to care for the VLA's equipment, software, people, and science. ‣ Astronomers perform their own research projects as well as help international users with data reduction, project planning, observing advice, and on-site guidance. ‣ Engineers oversee, confer, design, and re-design equipment and software. ‣ Array operators work with observers and scientists whose tests or observations are running, monitor the antennas, and communicate with technicians in the field. ‣ A variety of mechanics, technicians, and machinists maintain, repair, and fabricate the VLA's many specialized parts. Drafters maintain plans and schematics for buildings, labs, shops, and antennas. ‣ Electricians maintain power to the antennas and buildings. ‣ Transporter crew drives and maintains the two giant transporters used to lift and move the antennas to new pads and for maintenance. Track crew maintains the more than forty miles of double railroad track used to transport the antennas. ‣ Other people at the VLA include grounds crews, carpenters, warehouse managers, safety officers, public outreach staff, carpenters, painters, and support staff.

EXPLORE A VLA ANTENNA	CONTENT
A large interactive graphic of a telescope labels the major parts and allows visitors to explore its different components to learn how they work and how they are updated and maintained. An adjacent interactive allows visitors to change the array's configuration from A to B to C to D and see how the different configurations yield different resolutions.	‣ The VLA includes 27 radio antennas arranged in a Y-shaped array and all the equipment, instrumentation, and computing power needed to function as an astronomical interferometer. ‣ An interferometer is an array of separate antennas or telescopes that are connected together to work as a single telescope with a diameter equal to the spacing of the antennas, increasing the total signal collected and providing higher resolution images. Array Configurations ‣ The VLA is reconfigurable and uses four principle array configurations, A through D. » *The A-configuration provides the longest baselines and thus the highest angular resolution for a given frequency, but yields very limited sensitivity to surface brightness.* » *The D-configuration provides the shortest baselines, translating to a high surface brightness sensitivity at the cost of angular resolution.* ‣ Over the course 16 months, the VLA lengthens each of its arms from two-thirds of a mile to 23 miles long. The North arm is 11 miles long, two other arms are 13 miles long. Antennas ‣ Each of the VLA's 28 antennas (including the one that is a spare) is an 82-foot dish with 8 receivers tucked inside. The dish moves on an altitude-azimuth (classic tripod) mount that tilts up and down and spins around. » *Dish size: 25 meters.* » *Weight: 230 tons.* » *Dish Surface: Aluminum panels accurate up to .5 mm.* » *BUS: Steel.* » *Frequencies: From 1.0 GHz to 50 GHz.* ‣ The telescopes are moved on rails. Every four months, a specially-designed rail truck, called a Transporter, picks up telescopes and hauls them one at a time farther down their track. People ‣ Antenna mechanics take care of the surface and structural aspects of the antennas. ‣ Machinists make parts for nearly every sector of the observatory, from small electronics to large feed horn prototypes. ‣ The technicians in the cryogenics lab build and maintain the refrigeration systems that cool the electronics inside the vertex room of the antennas. Helium gas cools the receiver systems down to about 15°Kelvin, or -432°Fahrenheit. The technicians must work in a clean environment that sometimes requires them to wear white cotton gloves when handling the components. If oil from their hands gets on the components, it will freeze and act as an (unwanted!) insulator. ‣ Servo Mechanics: A Servo Shop is responsible for maintaining the electronics on the 300-pound servo motors that point the antennas. ‣ Welders use Metal Inert Gas (MIG), Tungsten Inert Gas (TIG), shielded arc, and oxyacetylene welding techniques as well as brazing and soldering. They can also do plasma welding and cutting, if needed.

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."

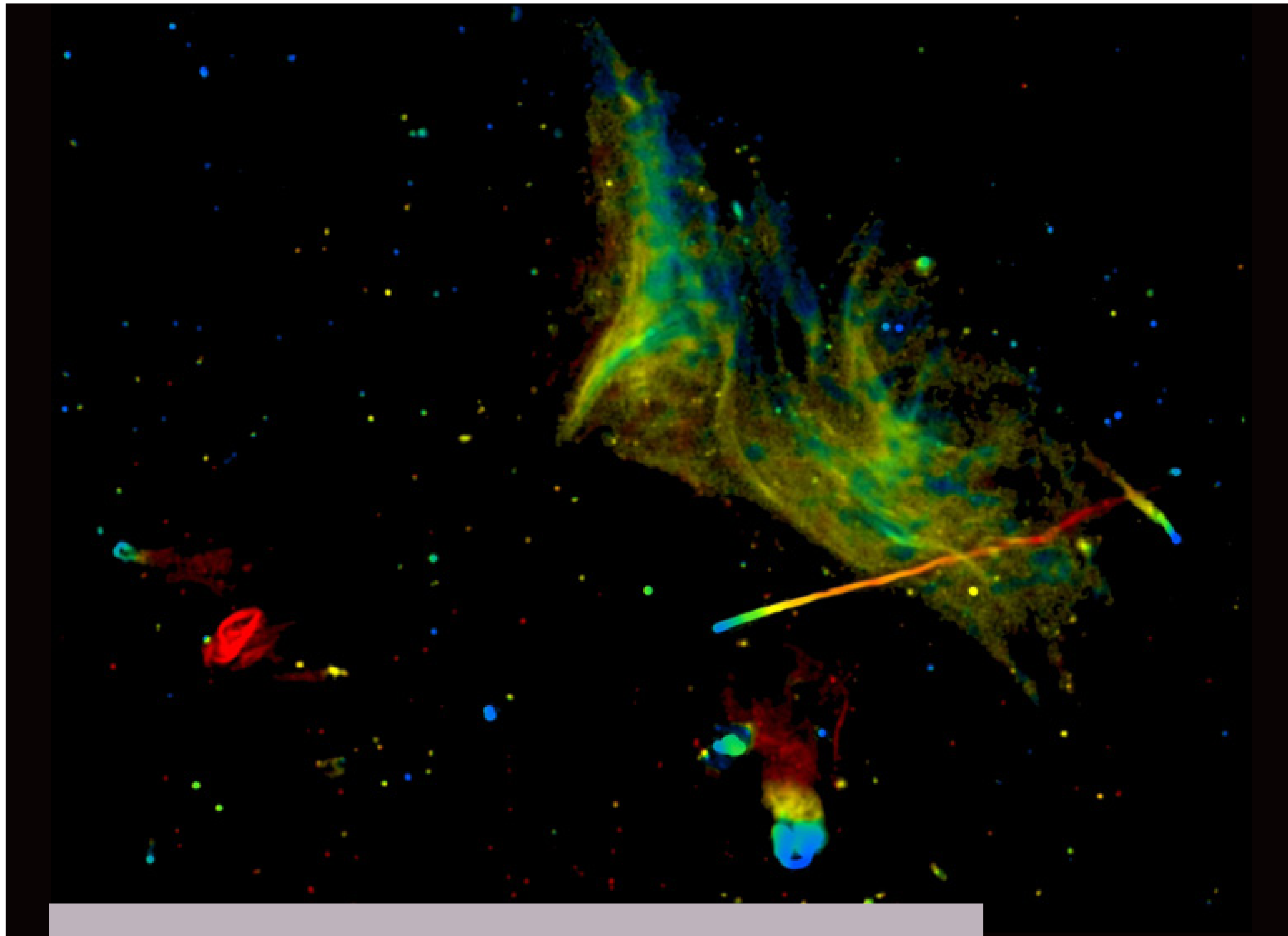
— *Albert Einstein*

EXPLORE THE VLA: CONTROL ROOM	CONTENT
The CONTROL ROOM exhibit is located in a shielded area on the back side of the theater. Staged to look like the actual control room, visitors learn how array operators monitor multiple computers at several different multimedia interactive stations. Exhibit elements could include mock-ups of the types of real-time information operators must monitor, such as name and coordinates of the source being observed, antenna position, tracking status, frequency band, weather readings, and system faults and alerts, as well as a sample of an observing log from a typical observation. This area also interprets the mind-boggling number-crunching powers of the WIDAR Supercomputer. Other interactive ideas include Ask An Astronomer and the VLA Sky Survey.	‣ Array operators are responsible for operating the radio telescope and running astronomical observations, monitoring several screens containing hundreds of readings of real-time information, including: » *All of the telescope's systems as well as the raw astronomical data it is gathering to ensure the integrity of each scientific observation.* » *Personnel and equipment safety by keeping track of and communicating with personnel working out on the array.* ‣ Array operators maintain detailed observation logs for each observation, documenting weather conditions, problems that may cause data loss or corruption, and other issues observers need to know about. WIDAR Supercomputer ‣ The WIDAR (Wideband Interferometric Digital Architecture) can perform 16 quadrillion operations every second. ‣ Designed and built by our partners at the National Research Council in Canada, who came up with a new method of combining data. ‣ Is housed in its own Faraday cage, a grounded metal screen that contains the EM radiation produced by the computer to keep it from interfering with the weak cosmic signals the array is observing.

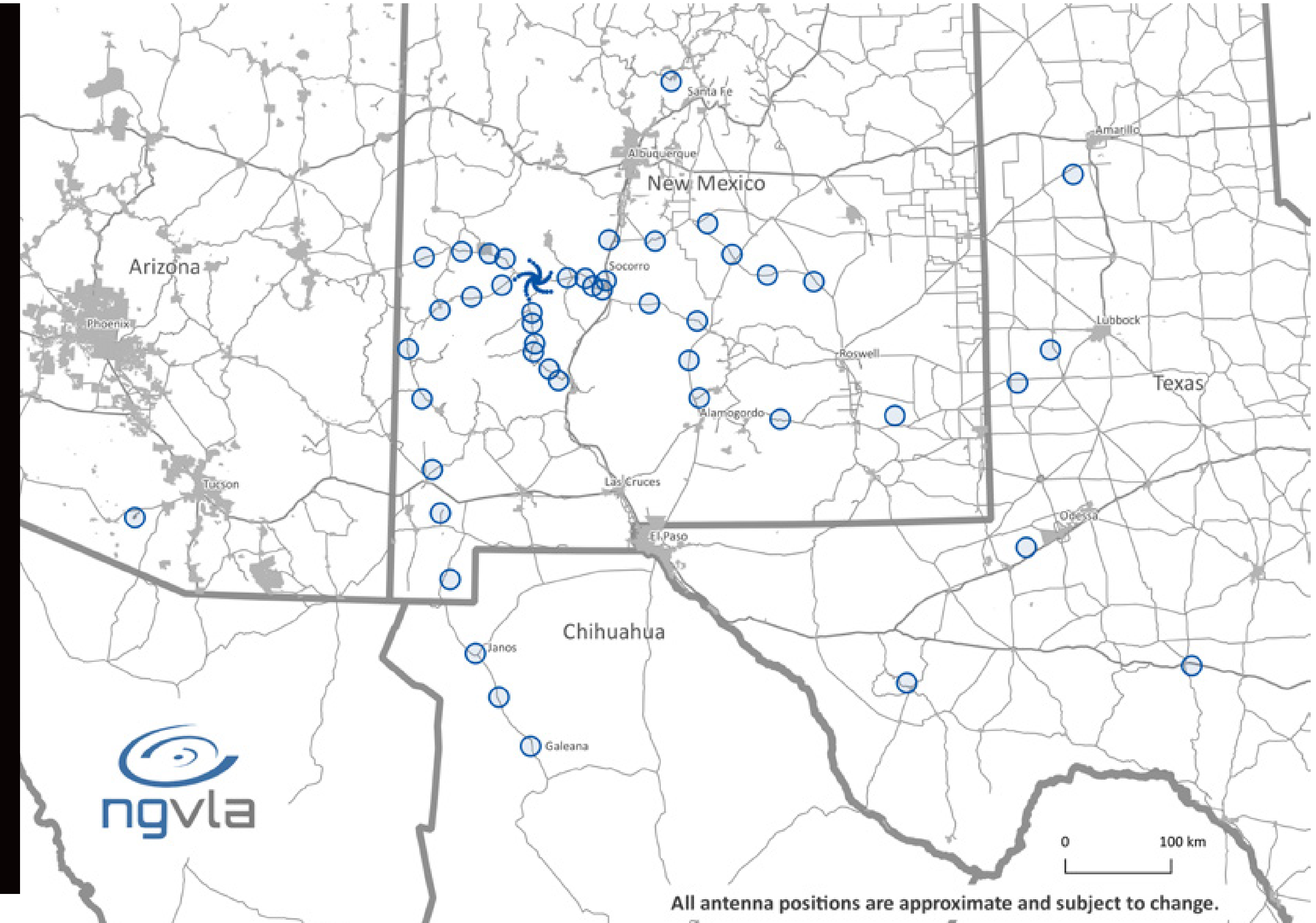
VLA DISCOVERIES	CONTENT
VLA discoveries, along with iconic images and portraits of people involved in them, are interpreted on three-sided spinning exhibit. Major updates and renovations are included as well. This area provides another opportunity to highlight modern artwork inspired by VLA discoveries or other astrological phenomenon.	‣ VLA discoveries have fundamentally changed what we know about space—from our home planet to the edges of the detectable universe. ‣ All of us—scientist and non-scientist alike—share in and benefit from the discovery process. ‣ Key observations of black holes. ‣ Protoplanetary disks around young stars. ‣ Serendipitous discoveries. ‣ 1987: 1st "Einstein Ring" gravitational lens. ‣ 1991: water ice on Mercury. ‣ 1994: 1st "microquasar" within Milky Way Galaxy. ‣ 1997: 1st detection of radio emission from a Gamma Ray Burster. ‣ 2017: supernova explosion or an outburst from a second supermassive black hole near the Cygnus A galaxy's center.

ngVLA	CONTENT
Against the backdrop of an artist's conception of the multi-antenna Next-Gen VLA (ngVLA), visitors learn about the National Radio Astronomy Observatory (NRAO) and Associated Universities, Inc. (AUI) are launching a new initiative to design a next-generation radio telescope with scientific capabilities far beyond those provided by any existing or currently proposed observatory.	▸ The next-generation VLA will be designed to provide the next leap forward in our understanding of planets, galaxies, black holes, and fundamental physics. ▸ The new array will have more than 200 antennas extending across the desert southwest of the United States and into northern Mexico, giving it 10 times more collecting area and 10 times more resolution of the current VLA and ALMA. » *Consist of 214 18-meter dishes extending up to ~1000 km baselines.* » *Extend the operational frequency range from 25cm (1.2 GHz) to 2.6 mm (116 GHz).* » *Achieve an angular resolution ranging between ~0.5 and 50 milli-arcsecond (mas).*

WHAT'S IN A COLOR?	CONTENT
In this interactive, based on NRAO's popular online Cosmic Coloring Compositor, visitors learn that false color images are used to help people visualize the data gathered by the VLA. They learn that false color is not the same as fake color as they are challenged to make the invisible universe visible by changing the wavelengths of radio, infrared, ultraviolet, and X-ray to colors human eyes can recognize. Visitors also compare images from VLA and other types of telescopes and learn how VLA works to detect both faint and faraway signals.	▸ Astronomers can create spectacular, multi-wavelength images by combining data from telescopes spanning nearly the entire range of the electromagnetic spectrum, from the long radio waves seen by VLA to the shorter x-rays, on the opposite end of the spectrum, observed by NASA's Chandra X-Ray Observatory. ▸ Most astronomical images created from invisible radio waves are converted to digital signals and assigned a color. ▸ The colors used in "False Color" images are not random or fake. The invisible wavelengths of radio, infrared, ultraviolet, and X-ray are represented with colors we can see, allowing us to "see" and discover many amazing details of the invisible universe. ▸ Most often this is done to highlight interesting features of the object in the image, as well as to make the data more meaningful.



In 2015, the VLA produced the most detailed image yet of a fascinating region of space 800 million light-years away called Abell 2256 where clusters of hundreds of galaxies are colliding, creating a rich variety of mysterious phenomena visible only to radio telescopes. This “true color” image shows how the region would appear if human eyes were sensitive to radio waves instead of light waves. In this image, red shows where longer radio waves predominate, and blue shows where shorter radio waves predominate, following the pattern we see in visible light.



The new array will have more than 200 antennas extending across the desert southwest of the United States and into northern Mexico, giving it 10 times more collecting area and 10 times more resolution of the current VLA and ALMA.

ESTIMATE SUMMARY

Estimate Assumptions:

This estimate is based on the Concept Drawings received by May 25, 2018.

The escalation rate used is 6% per year. Costs are escalated to the mid-point of construction of February, 2021.

An escalation rate above 6% per year is not included in the estimate. This is important if general inflation exceeds this rate.

The estimate should be recalculated if escalation rates increase and/or if this estimate is older than six months.

All soft costs are the owner's responsibility to determine and verify. The Soft Costs estimate has been excluded from the construction cost estimate.

Hazardous material abatement is included.

Estimate Qualifications:

Summary sheet markups are cumulative, not additive. Percentages are added to the previous subtotal rather than the direct cost subtotal.

Estimated labor is based on an 8 hour per day shift 5 days a week, first shift. Accelerated schedule work of overtime has not been included.

Estimate is based on a competitive public bid with at least 3 bona fide submitted and unrescinded general contractor bids.

Estimate is based on a competitive public bid with a minimum 6-week bidding schedule and no significant addendums within 2 weeks of bid opening.

Estimate is based on a 'Buy America' provisions for materials and services for the project.

Estimated construction cost is for the entire project. This estimate is not intended to be used for other projects.

Division 0/ Division 1 specifications are presumed to have normal ranges for liquidated damages, construction schedule and terms & conditions.

These divisions are typically written after the final estimate. Please contact the cost estimator for a review, if desired.

Please consult the cost estimator for any modifications to this estimate. Unilaterally adding and deleting markups, scope of work, schedule, specifications, plans and bid forms could incorrectly restate the project construction cost.

The construction cost estimate does not include an estimate of owner soft costs such as A/E fees, owner contingencies and permit fees.

Construction reserve contingency for change orders is not included in the estimate.

Any modifications to the plans via addendums and code review for permits will cause cost increases and are not included in this estimate.

Sole source supply of materials and/ or installers typically results in a 40% to 100% premium on costs over open specifications.

Contractors imposing different bidding conditions from plans and specifications on subcontractors are not bidding from the plans and specifications.

Modifications to the proposed construction schedule and modifying the phasing plans after this estimate will affect construction cost and are not included.

The estimate includes a reasonable construction escalation that can be determined based on market conditions for up to the next 6 months.

Since this project has a midpoint of construction further than 6 months, increases in escalation are not included beyond the rate shown in the estimate.

			Interpretive Center Building Remodel	$ 1,994,833
			Sitework	$ 2,264,644
			TOTAL DIRECT COST	$ 4,259,477
Design Contingency	20.0%	$ 851,895	*Subtotal*	$ 5,111,372
General Conditions	10.0%	$ 511,137	*Subtotal*	$ 5,622,510
Home Office Overhead	5.0%	$ 281,125	*Subtotal*	$ 5,903,635
Profit	5.0%	$ 295,182	*Subtotal*	$ 6,198,817
Escalation to midpoint of construction - February, 2021	17.3%	$ 1,073,772	*Subtotal*	$ 7,272,589
TOTAL ESTIMATED CONSTRUCTION COST - FEBRUARY, 2021				**$ 7,272,589**

See Appendix A for estimate detail.

Four times a year, a specially-designed rail truck, called a transporter, picks up telescopes and hauls them one at a time farther down their track to change the array configurations.

NEXT STEPS

Exhibit design and development is a multi-phase process that is guided by the themes and stories arising from the resource, visitors' intrinsic interests, and the mission and goals of the organization.

Based on comments and direction on this Interpretive Master Plan, the project would move through Concept Design, Design Development and Final Design phases before the final Fabrication and Delivery phase.

Concept Design

Concept Design includes conceptual floor plan and elevations of individual exhibits. A written exhibit outline organizes topics into a storyline, describes specific content to be presented in each exhibit, and provides descriptions of suggested exhibit methods for delivering the content to visitors.

Design Development

The project moves to a higher level of detail in Design Development. During this phase, specific exhibit elements are developed, exhibit text and audiovisual scripts are written, graphic layouts are developed, objects and images are cataloged, and interactive exhibit concepts are evaluated.

Final Design

During the final phase of design, the project is taken to its completed level of detail prior to fabrication.

Photo credits / acknowledgments:

Front cover: Primordial Galaxies Swimming in Vast Ocean of Dark Matter. NRAO/AUI/NSF; D. Berry.

Page 2: Radio-Optical View of the Galaxy Hercules. NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA).

Page 3: © Kavli Institute for Cosmology, Cambridge, University of Cambridge/Amanda Smith.

Page 4: VLA at sunset, 2002. Image courtesy of NRAO/AUI/NSF

Page 6: VLA array. Image courtesy of NRAO/AUI/NSF.

Page 8: Abell 2256. Owen et al., NRAO/AUI/NSF.

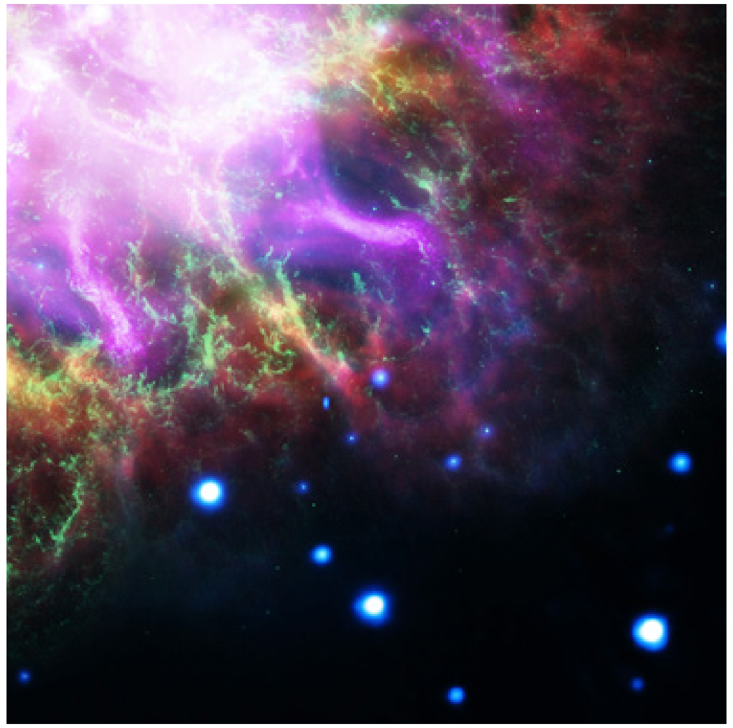
Page 33: Abell 2744. Pearce et al.; Bill Saxton, NRAO/AUI/NSF; Chandra; Subaru; ESO.

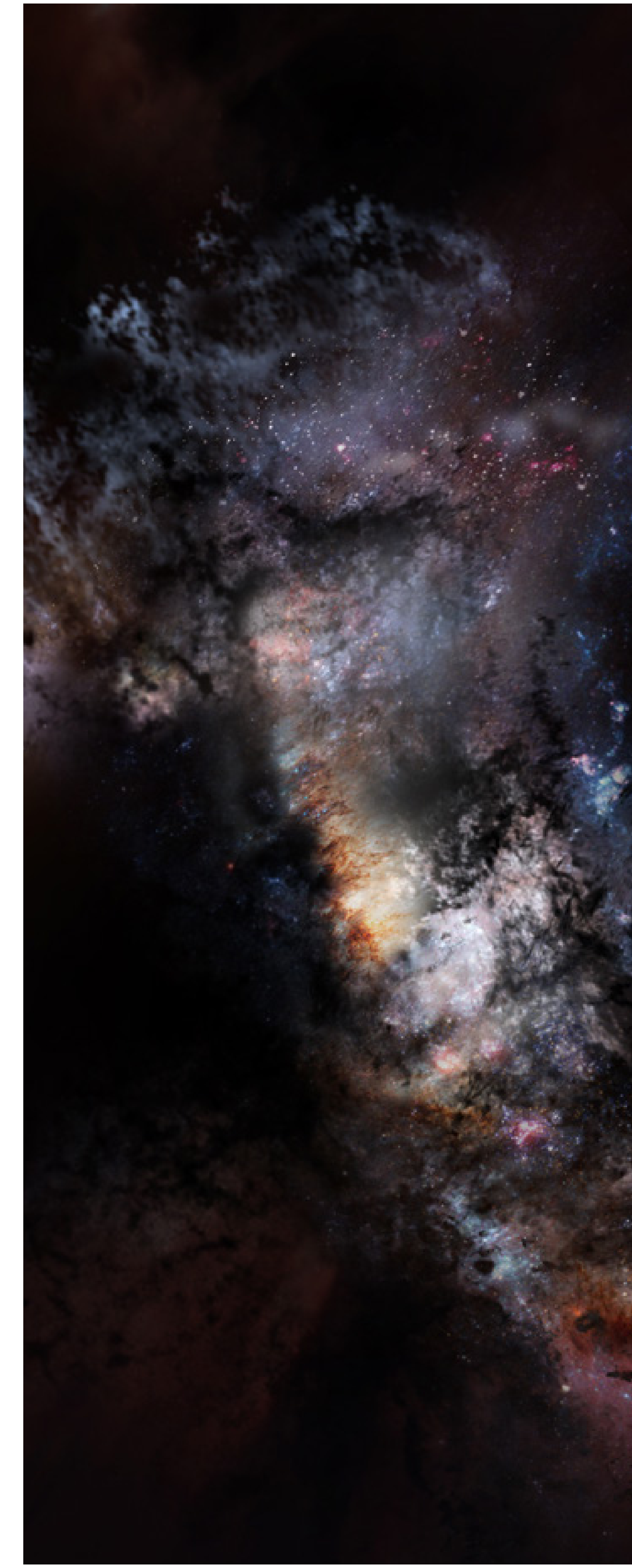
Page 35: VLA array. Image courtesy of NRAO/AUI.

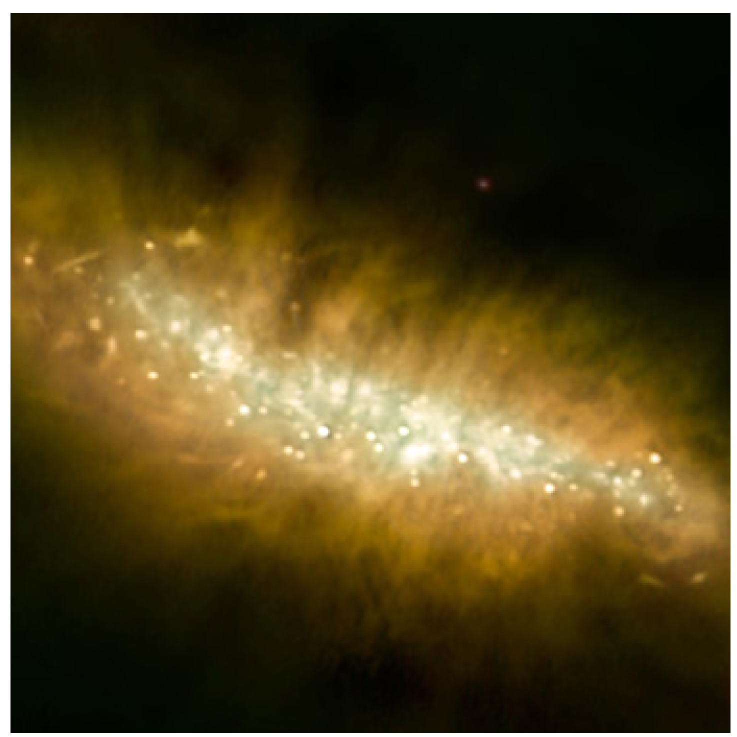
Page 37: Crab Nebula. G. Dubner (IAFE, CONICET-University of Buenos Aires) et al.; NRAO/AUI/NSF; A. Loll et al.; T. Temim et al.; F. Seward et al.; Chandra/CXC; Spitzer/JPL-Caltech; XMM-Newton/ESA; and Hubble/STScI.

Back cover: VLA image courtesy of NRAO/AUI/NSF and Photo by Amy DuVall; Starbursting in Galaxy M82, Josh Marvil (NM Tech/NRAO), Bill Saxton (NRAO/AUI/NSF), NASA.


VLA







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