VERA C. RUBIN
OBSERVATORY

U.S. National Science Foundation

U.S. Department of ENERGY | Office of Science

NSF–DOE Vera C. Rubin Observatory

Media Kit

14 Jan 2025

RubinObservatory.org

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Copy Style and Visual Identity

Observatory Name

First reference, if U.S. National Science Foundation and U.S. Department of Energy have not been referenced earlier:
NSF–DOE Vera C. Rubin Observatory, funded by the U.S. National Science Foundation and U.S. Department of Energy's Office of Science

Otherwise, on first and second references or if space is limited, any of the following:

- NSF–DOE Vera C. Rubin Observatory
- NSF–DOE Rubin Observatory
- NSF–DOE Rubin

Subsequent references, any of the following:

- Vera C. Rubin Observatory
- Rubin Observatory
- Rubin

Please do NOT use:

- VRO
- Rubin Telescope

Survey

First mention: Legacy Survey of Space and Time (LSST)

Camera

First mention: LSST Camera

Telescope

First mention: Simonyi Survey Telescope

Please do not use:

- SST

Summary Statement

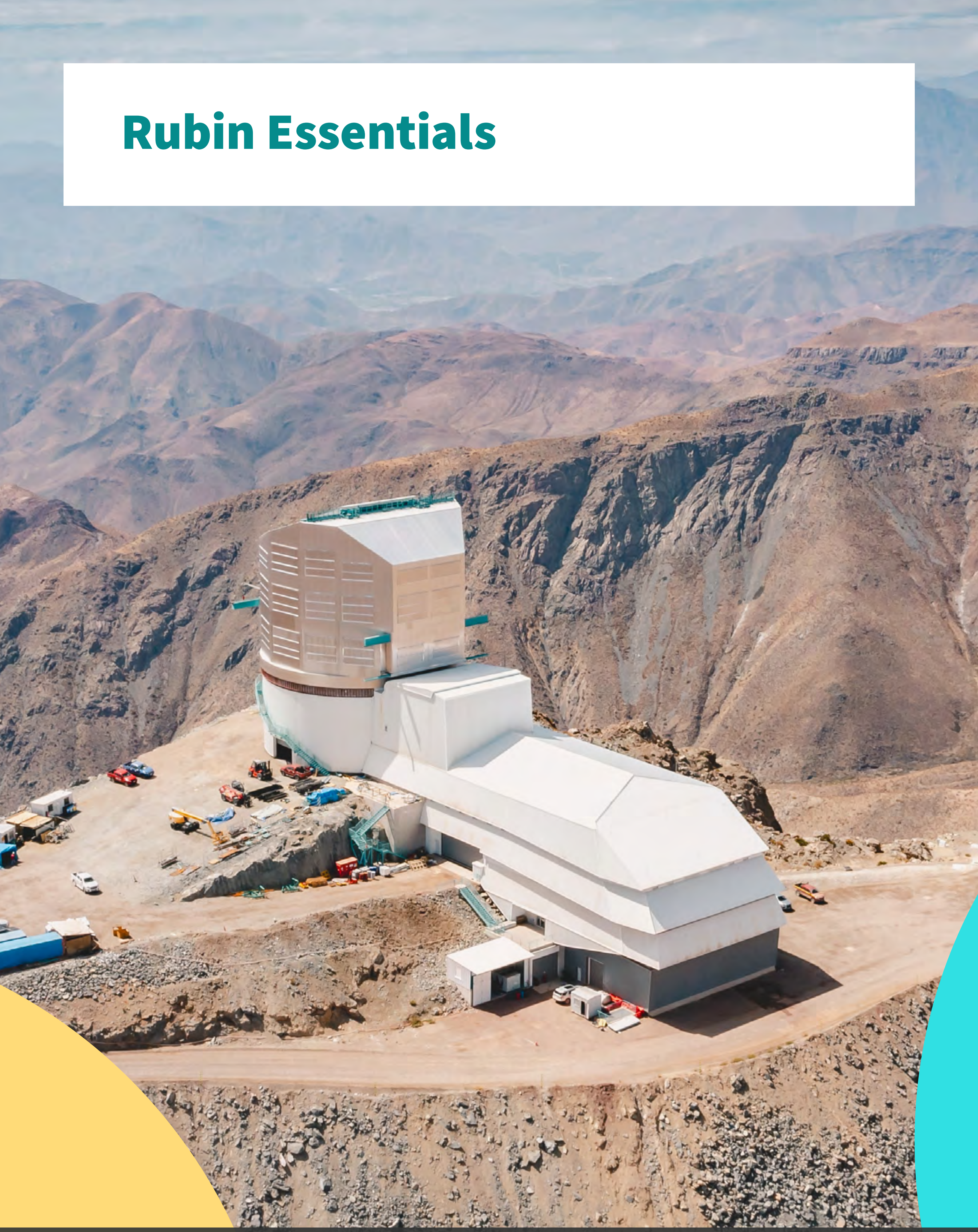
NSF–DOE Vera C. Rubin Observatory, funded by the U.S. National Science Foundation and the U.S. Department of Energy's Office of Science, will perform the Legacy Survey of Space and Time using the LSST Camera and the Simonyi Survey Telescope. Rubin Observatory is a joint Program of NSF NOIRLab and DOE's SLAC National Accelerator Laboratory.

Visual Identity

Rubin's Visual Identity guidelines and approved logos are also linked from the footer of rubinobservatory.org

Visual Identity

Rubin Essentials



Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

1. NSF–DOE Rubin Observatory will revolutionize the way we explore the cosmos.

NSF–DOE Vera C. Rubin Observatory, funded by the U.S. National Science Foundation (NSF) and the U.S. Department of Energy's Office of Science (DOE/SC), will change our understanding of the Universe. From a mountaintop in Chile, Rubin Observatory will repeatedly scan the sky for 10 years with the largest camera ever built, creating an ultra-wide, ultra-high-definition, time-lapse record of our Universe. Named after astronomer Vera C. Rubin, who provided the first convincing evidence for the existence of dark matter, Rubin Observatory will conduct a 10-year survey called the Legacy Survey of Space and Time (LSST). Each point on the southern sky will be imaged about 800 times during the LSST.

Rubin Observatory is the first of its kind: its mirror design, camera size and sensitivity, telescope speed, and computing infrastructure are each in an entirely new category.

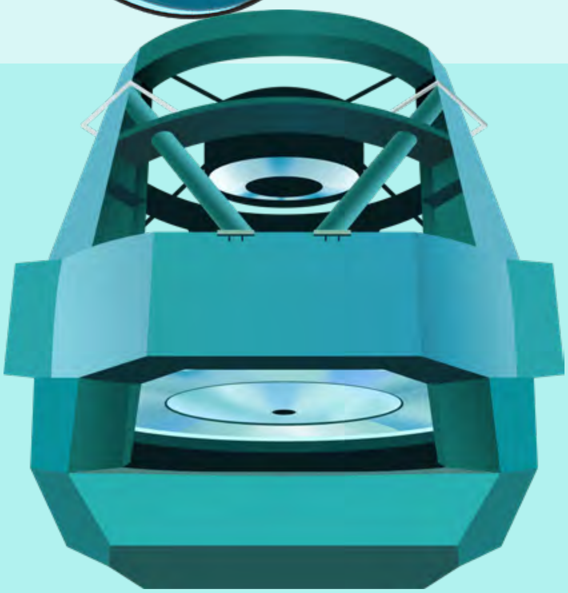
The 8.4-meter Simonyi Survey Telescope at Rubin Observatory, equipped with the LSST Camera — the largest camera ever built — will take detailed images of the southern hemisphere sky for 10 years, covering the visible sky every few nights and creating the largest astronomical movie of all time. This unique movie will bring the night sky to life, yielding a treasure trove of discoveries: asteroids and comets, pulsating stars, and supernova explosions. With Rubin data we will all understand our Universe better, chronicle its evolution, delve into the mysteries of dark energy and dark matter, and reveal answers to questions we have yet to imagine.

The night sky dazzles over Rubin Observatory in this shot from October 2024. The Milky Way sprawls overhead in the waning light of sunset. Venus shines brightly on the left, while Comet C/2023 A3 (Tsuchinshan–ATLAS) appears just above the observatory at center. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/H. Stockebrand

2. Rubin Observatory is packed with innovative technology.

LSST Camera

- The 3200-megapixel, car-sized LSST Camera is **the largest camera ever built.** The camera can capture 45 times the area of the full moon in the sky with each exposure.
- The **images** it will produce are so large that it would take 400 ultra-high-definition televisions to display one of them at full size.



Simonyi Survey Telescope

- The Simonyi Survey Telescope's unique 8.4-meter **combined primary/tertiary mirror** consists of two optical surfaces on one piece of glass.
- The telescope's drive system, rigid design, and **compact shape** allow it to be ready for its next image in just five seconds — faster than any other telescope of its size.

Data

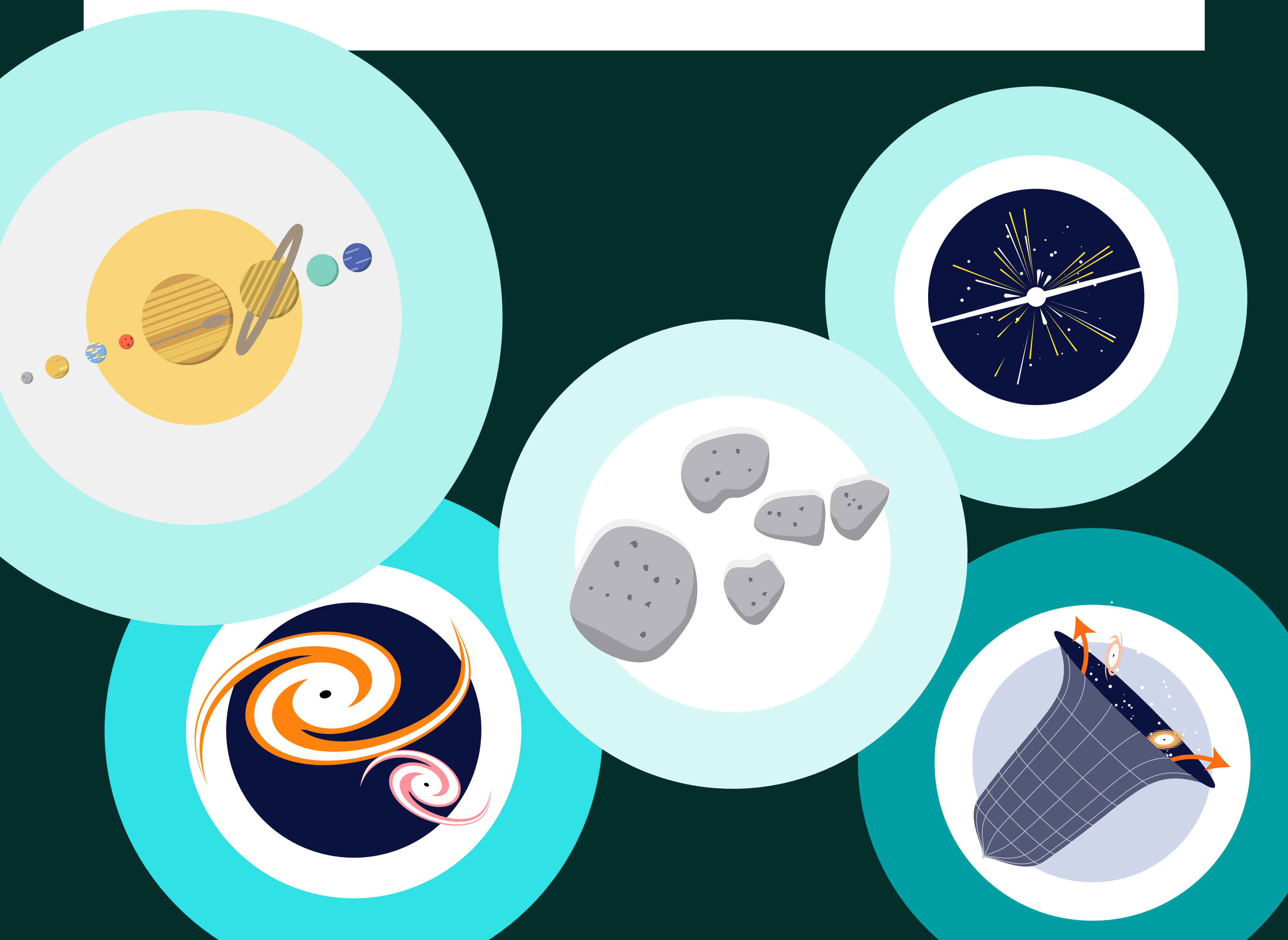
- Rubin's **data management system** will transfer and process 20 terabytes of astronomical data every night.
- Rubin's **software** will automatically compare new images with previous ones and generate an alert for each change detected in the sky — about 10 million per night.

3. Rubin Observatory will bring the night sky to life, yielding a treasure trove of discoveries: asteroids and comets, pulsating stars, and supernova explosions.

If it moves, flashes, or pulses, Rubin will catch it in action. As Rubin takes new images, its cutting-edge software automatically compares these new images to a template made from previous images. When a change is detected Rubin will issue an alert within minutes, available to anyone in the world.

With the help of these alerts, scientists will be able to observe exploding stars before they fade away, identify millions of faint asteroids and comets we've never seen before, and address all kinds of brand new mysteries.

Rubin Observatory is capable of detecting millions of changes in the southern sky every night, including discovery of nearby asteroids that could impact Earth.



4. Rubin Observatory is a powerful new tool to answer a wide range of science questions.

Rubin is designed to make all kinds of science possible with a single survey. Rubin's enormous dataset will unlock mysteries in countless areas of astronomy and astrophysics, including: helping scientists answer questions about dark matter and dark energy; the structure and evolution of the Milky Way; the formation of our Solar System; and black holes, exploding stars, or other things that go "bump" in the night.

Rubin's enormous data set will unlock mysteries in countless areas of astronomy and astrophysics.

The early days of Rubin's 10-year survey will see an explosive period of discovery, as new asteroids, comets, and even visiting interstellar objects come into view for the first time. As the survey continues, Rubin's accumulated data will also reveal more subtle phenomena, like weak gravitational lensing and the faint glow of light between galaxies in massive galaxy clusters, that provide researchers with clues about the overall structure and evolution of the Universe.

Rubin was specifically designed to address questions in four science areas, with the capability for an even broader range of scientific investigations:

- Understanding the nature of dark matter and dark energy
- Creating an inventory of the Solar System
- Mapping the Milky Way
- Exploring the changing sky

Milky Way Structure & Formation

Dark Matter & Dark Energy

Solar System Census

The Changing Sky

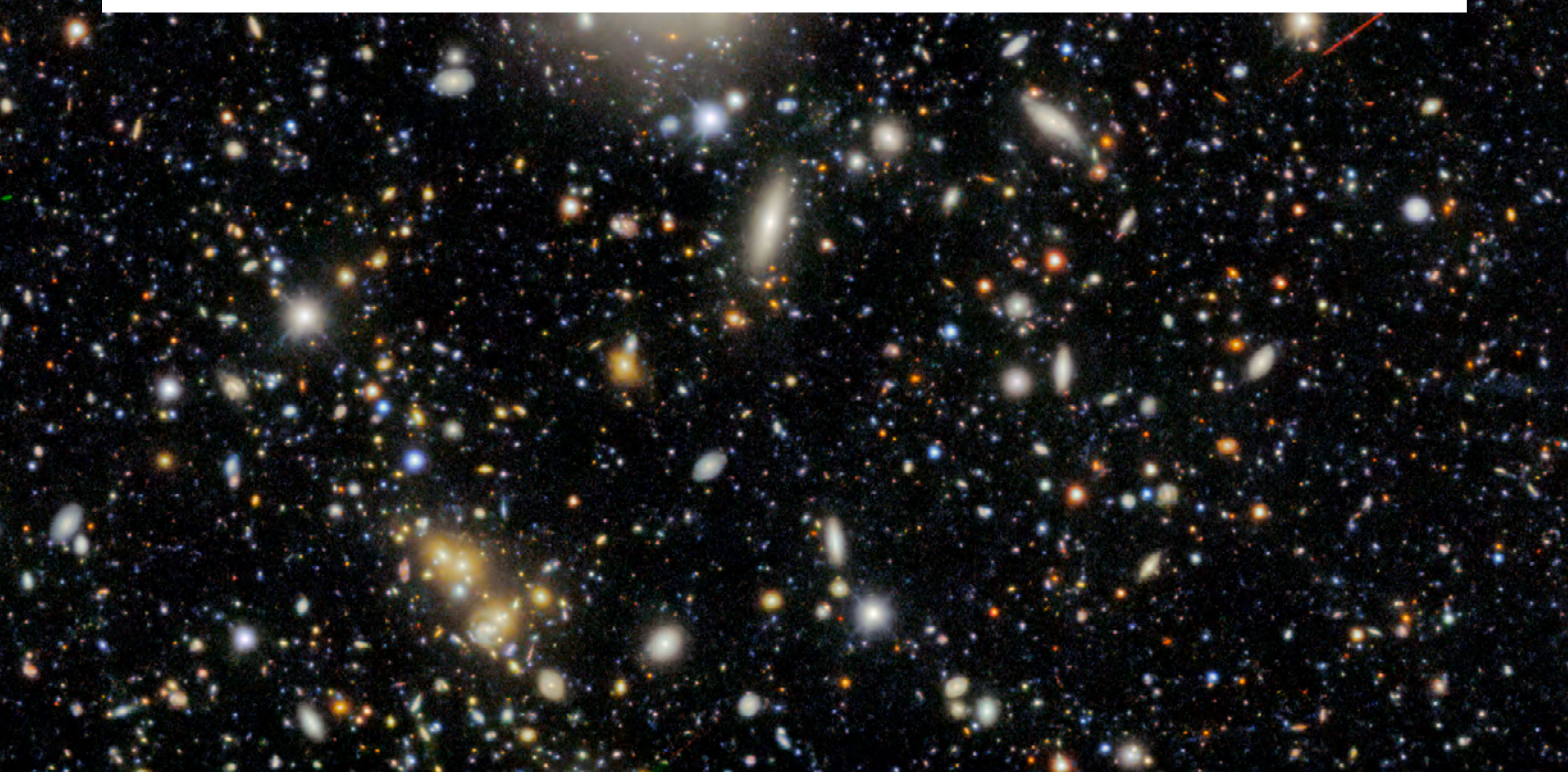
5. Rubin Observatory will reveal questions we don't yet know to ask.

When Rubin begins operating in 2025, it'll be like turning on a firehose of astronomical data.

Rubin's combination of speed, wide field of view, and sensitive camera expands the limits of what a telescope can do. No other telescope has been able to detect both real-time changes in the sky and faint or distant objects at the same time on this enormous scale. These capabilities mean that exceedingly rare events in the sky, never detected before, will be captured for the first time.

Scientists preparing for Rubin data have worked hard to predict the types of discoveries that will come from the 10-year LSST, but they're ready — and excited — to be surprised too. Rubin's never-before-seen capabilities will lead to unpredicted discoveries and reveal questions we do not yet know to ask, helping us understand more about the Universe and our place in it.

Every time we look at the Universe in a new way, we make new discoveries we never could have predicted. With Rubin, scientists will have access to more data about our Universe than ever before.



Dark Energy Survey/DOE/FNAL/DECam/CTIO/NOIRLab/NSF/AURA Acknowledgments: T.A. Rector (University of Alaska Anchorage/NSF NOIRLab), J. Miller, M. Zamani & D. de Martin (NSF NOIRLab)

6. People and organizations all around the world make Rubin possible.

Rubin Observatory is located in Chile, and is jointly funded by the U.S. National Science Foundation and the U.S. Department of Energy's Office of Science. Rubin Observatory is a joint Program of NSF NOIRLab and DOE's SLAC National Accelerator Laboratory.

State-of-the-art facilities that store and process Rubin data include: the US Data Facility in California; the France Data Facility in Lyon; and the UK Data Facility, a network across the United Kingdom.

Rapid transfer of data is enabled by a high-speed long-haul network connecting Chile and California, made possible by Latin America's Research and Education Networks (RENs), with contributions from Brazil and Florida International University.

Most of the observatory's hardware and software components were designed at institutions across the U.S. The 8.4-meter combined primary/tertiary mirror was fabricated in Arizona, the 3.5-meter secondary mirror in New York, and most of the LSST Camera systems in California. The camera filter exchange system was built in France, the telescope mount in Spain, and other system components in a number of other countries.

Organizations around the world provide in-kind contributions in exchange for access to Rubin data before they become world-public (two years after being released to scientists with data rights).

The LSST Discovery Alliance, headquartered in Tucson, Arizona, is an independent, non-profit organization that delivers programs and facilitates resources and funding to help scientists analyze and draw meaning from Rubin data.

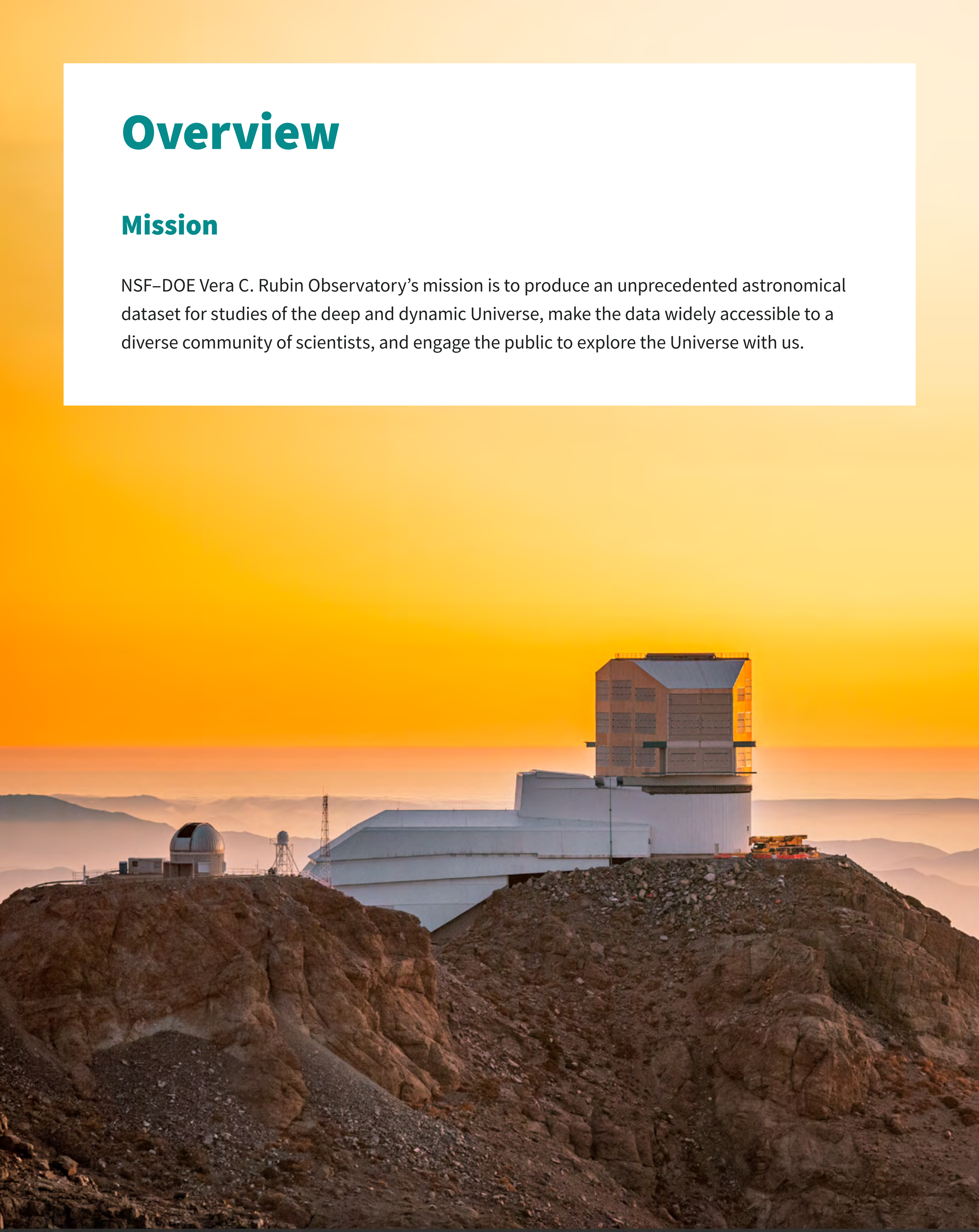
And then there are the scientists themselves: networks of thousands of professional researchers from all over the world — sometimes with participation from members of the public — contributing to countless projects with the common goal of advancing our understanding of the Universe.


Left: Rubin Observatory staff and scientists gather in Croatia in 2023. Credit: Fotostudio LICUL | Right: Members of the Rubin summit team on the maintenance floor of the observatory. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

Overview

Mission

NSF–DOE Vera C. Rubin Observatory's mission is to produce an unprecedented astronomical dataset for studies of the deep and dynamic Universe, make the data widely accessible to a diverse community of scientists, and engage the public to explore the Universe with us.

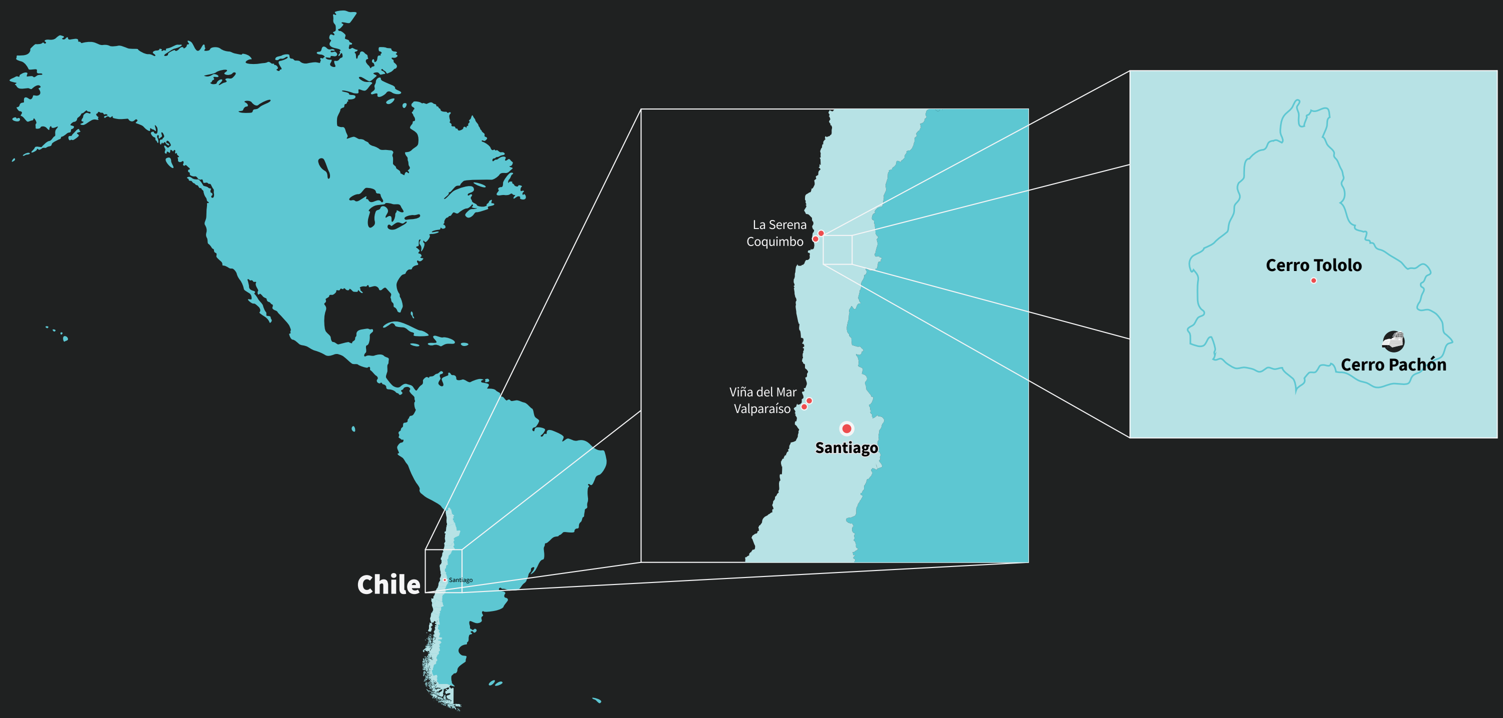


Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/P. Horálek

Location

Rubin Observatory's summit facility is located in Chile, on a mountain called Cerro Pachón. The 18-story observatory sits 2647 meters (8684 feet) above sea level. Rubin's mountaintop site has a long list of appealing qualities for ground-based astronomical observing, including relatively low levels of atmospheric turbulence, dry air, and a large number of days with clear skies.

Rubin has several neighbors — the Southern Observatory for Astrophysical Research (SOAR) and Gemini South telescopes are also located on Cerro Pachón, and the Cerro Tololo Inter-American Observatory (CTIO) sits on Cerro Tololo, just northwest of Cerro Pachón. All of the facilities in this area, including Rubin, are managed by the Association of Universities for Research in Astronomy (AURA) through agreements with NSF.



Rubin Observatory's location. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA

Funding & Management

NSF–DOE Vera C. Rubin Observatory is a joint initiative of the U.S. National Science Foundation (NSF) and the U.S. Department of Energy's Office of Science (DOE/SC). Its primary mission is to carry out the Legacy Survey of Space and Time, providing an unprecedented dataset for scientific research supported by both agencies. Rubin is operated jointly by NSF NOIRLab and SLAC National Accelerator Laboratory. NSF NOIRLab is managed by the Association of Universities for Research in Astronomy (AURA) and SLAC is operated by Stanford University for DOE. France provides key support to the construction and operations of Rubin Observatory through contributions from CNRS/IN2P3. Rubin Observatory is privileged to conduct research in Chile and gratefully acknowledges additional contributions from more than 40 international organizations and teams.

The U.S. National Science Foundation (NSF) is an independent federal agency created by Congress in 1950 to promote the progress of science. NSF supports basic research and people to create knowledge that transforms the future.

The DOE's Office of Science is the single largest supporter of basic research in the physical sciences in the United States and is working to address some of the most pressing challenges of our time.

NSF NOIRLab (U.S. National Optical-Infrared Astronomy Research Laboratory), the U.S. center for ground-based optical-infrared astronomy, operates the International Gemini Observatory (a facility of NSF, NRC–Canada, ANID–Chile, MCTIC–Brazil, MINCyT–Argentina, and KASI–Republic of Korea), NSF Kitt Peak National Observatory (KPNO), NSF Cerro Tololo Inter-American Observatory (CTIO), the Community Science and Data Center (CSDC), and NSF–DOE Vera C. Rubin Observatory (in cooperation with DOE's SLAC National Accelerator Laboratory). It is managed by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with NSF and is headquartered in Tucson, Arizona. The scientific community is honored to have the opportunity to conduct astronomical research on I'oligam Du'ag (Kitt Peak) in Arizona, on Maunakea in Hawai'i, and on Cerro Tololo and Cerro Pachón in Chile. We recognize and acknowledge the very significant cultural role and reverence that these sites have to the Tohono O'odham Nation, to the Native Hawaiian community, and to the local communities in Chile, respectively.

SLAC National Accelerator Laboratory explores how the Universe works at the biggest, smallest and fastest scales and invents powerful tools used by researchers around the globe. As world leaders in ultrafast science and bold explorers of the physics of the Universe, we forge new ground in understanding our origins and building a healthier and more sustainable future. Our discovery and innovation help develop new materials and chemical processes and open unprecedented views of the cosmos and life's most delicate machinery. Building on more than 60 years of visionary research, we help shape the future by advancing areas such as quantum technology, scientific computing and the development of next-generation accelerators. SLAC is operated by Stanford University for the U.S. Department of Energy's Office of Science.

View of Rubin Observatory at sunset in May 2024, on Cerro Pachón in Chile. Credit: Olivier Bonin/SLAC National Accelerator Laboratory

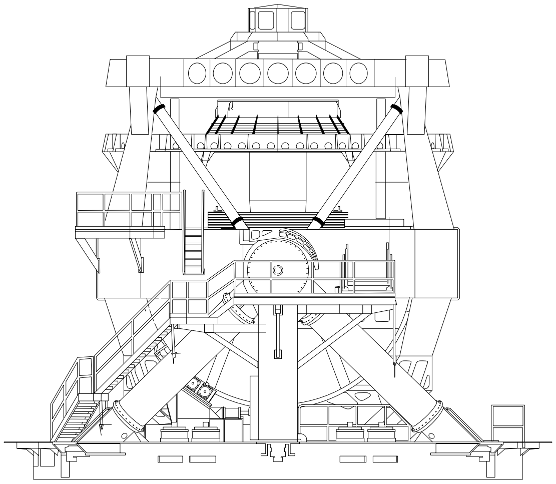
History and Naming

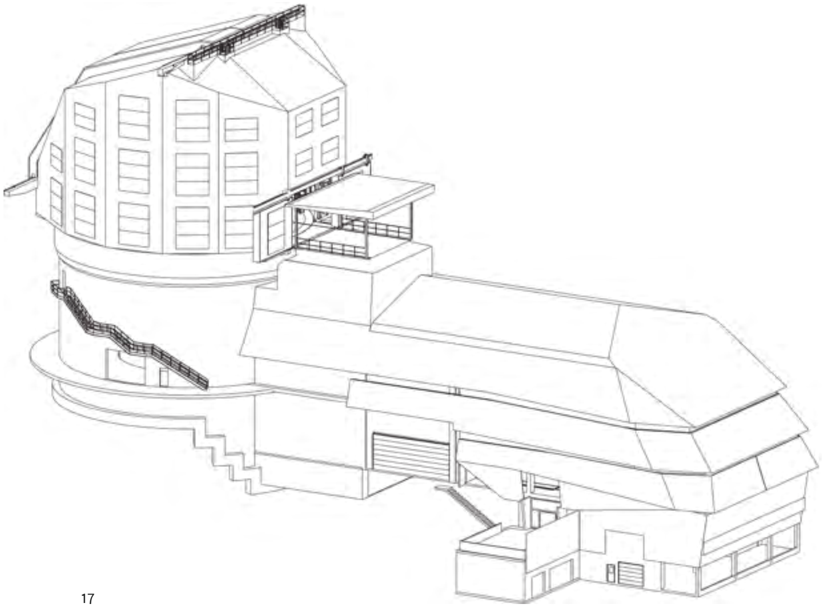
Scientists who began brainstorming this telescope in the 1990s originally called it the Dark Matter Telescope. They wanted to use this tool to learn more about dark matter, which we can't see but we know is there because of its gravitational effects on the stars and galaxies we observe. These effects are most obvious when studying the structure of the Universe on a large scale, so scientists began designing a telescope with an exceptionally wide field of view, enough speed to scan the entire visible sky in a matter of days, and the ability to see extremely faint objects. No previous telescope had ever combined all three of these qualities on this scale.

As the design of this groundbreaking new telescope evolved, it became clear that this tool would not only advance the study of dark matter, but countless other areas of astronomy and astrophysics as well. Excitement grew, and in 2007 the project received gifts from Charles Simonyi, Bill Gates, and Richard F. Caris to begin fabricating the 8.4-meter primary mirror, which was actually two combined optical surfaces on one glass structure — a first-ever design.

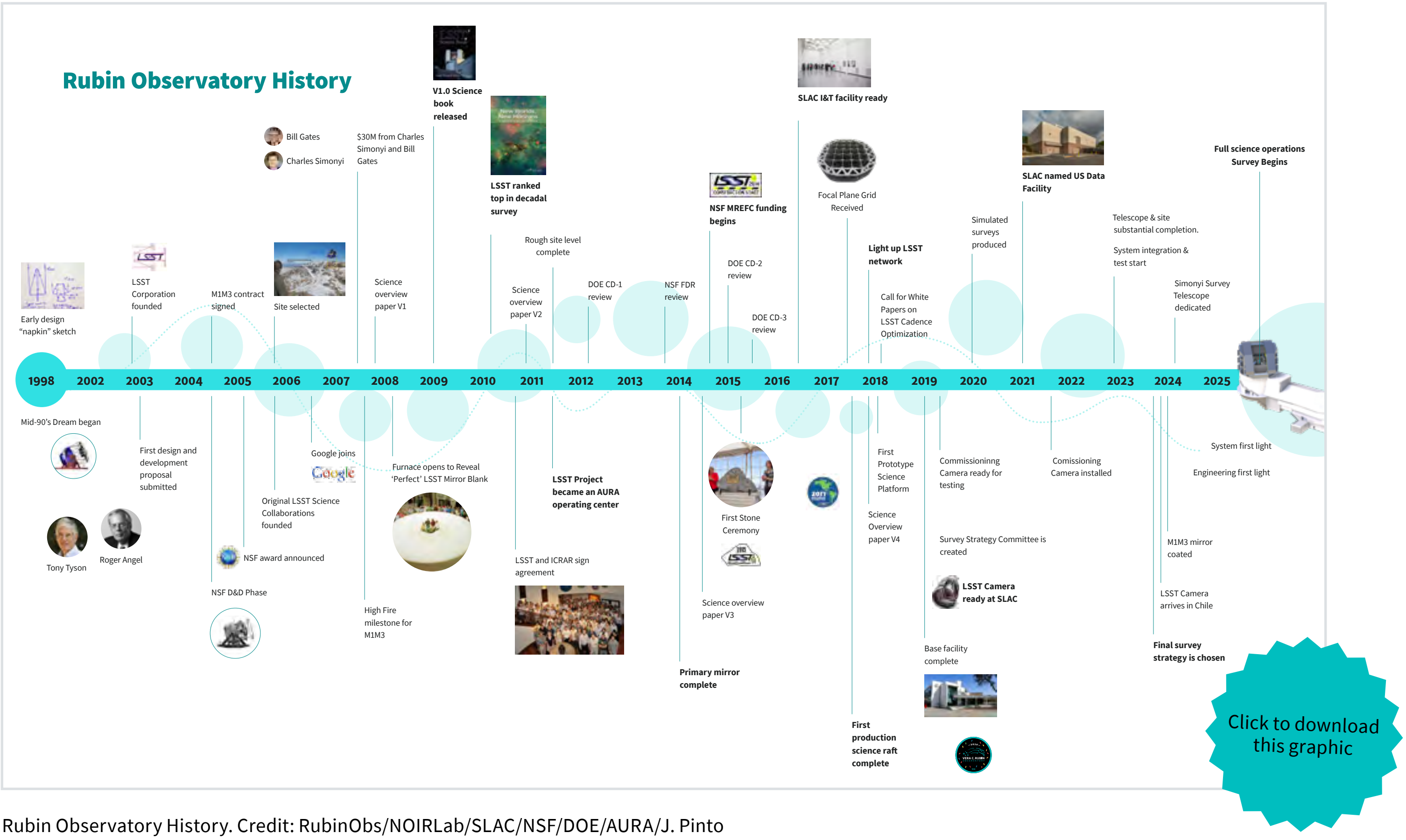
During the early development phases, its name was changed to the Large Synoptic Survey Telescope (LSST). In 2010, LSST was the top-ranked priority for ground-based astronomy in the National Academies 2010 Decadal Survey, which led to the approval of funding from the U.S. National Science Foundation (NSF) and the U.S. Department of Energy's Office of Science (DOE/SC). Construction of the observatory began on Cerro Pachón in 2015. The same year, scientists and engineers at SLAC National Accelerator Laboratory in California began developing the 3200-megapixel camera which would be at the center of the telescope. The size of a small car, this would be the largest digital camera ever built.

It became clear that this tool would not only advance the study of dark matter, but countless other areas of astronomy and astrophysics as well.





In 2019, an [act of the U.S. Congress](#) renamed the nearly complete, state-of-the-art facility poised to define the next decade of ground-based astronomy and beyond as Vera C. Rubin Observatory. The name honors a great American astronomer who advanced the field of astrophysics with her groundbreaking research on dark matter, and who worked to make science more accessible for everyone. The project subsequently named its amazing 10-year survey the Legacy Survey of Space and Time (LSST) in order to retain this now-familiar acronym alongside the historic namesake of the observatory.



Rubin Observatory History. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

In 2024, the telescope was named the Simonyi Survey Telescope to honor the Simonyi Family in light of the critical early gift from the Charles and Lisa Simonyi Fund for Arts and Sciences. That gift in 2007, supported by an additional gift from Bill Gates and earlier funds from Richard F. Caris, enabled the early development of the main mirror of the telescope. That mirror would become the novel primary/tertiary mirror for the system and was instrumental in reducing early risk for the (at the time) still-proposed project.

Who Will Use the Telescope and Data, and How

In short, everyone. Rubin is a survey observatory, meaning that it will collect all-purpose observations of the entire visible sky rather than targeting specific objects. Each night, Rubin will methodically image the sky according to a preplanned pattern called the "survey cadence." The vast majority (~90%) of its time is dedicated to the 10-year Legacy Survey of Space and Time (LSST). Most of the remaining time will be spent on smaller, targeted surveys with more specific purposes. About 3% of the observatory's time will be reserved for "Target of Opportunity" follow-up observations of exceptional or rare cosmic events.

Scientists will access Rubin data using an online portal called the Rubin Science Platform. For two years after they are collected, Rubin data will be available to U.S. and Chilean scientists, as well as international scientists who have agreements with the U.S. National Science Foundation, U.S. Department of Energy, or their delegates. After the two-year proprietary period, the data will be made world-public.

As Rubin scans the sky, its images will be automatically processed to detect objects that have changed in brightness or position — such as supernovae or asteroids. Alerts generated from these changes will be immediately world-public through a dedicated alert stream, allowing scientists around the world to conduct rapid follow up observations using other telescopes.

Finally, citizen scientists will also have an opportunity to help make discoveries with Rubin data. The Rubin team has partnered with Zooniverse to allow researchers to build projects that use Rubin data. This means there will be lots of ways for the public to help contribute to cutting-edge astronomy and astrophysics discoveries.

Rubin Observatory in October 2023. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

Observatory Namesake

Dr. Vera C. Rubin, American Astronomer

NSF–DOE Vera C. Rubin Observatory received its current name by an Act of U.S. Congress in December 2019, and it was announced at the American Astronomical Society Winter Meeting in January 2020. Previously named the Large Synoptic Survey Telescope (LSST), Rubin Observatory was the first national U.S. Observatory to be named after a woman.

Vera Rubin working at Kitt Peak National Observatory. Credit: Carnegie Institution for Science

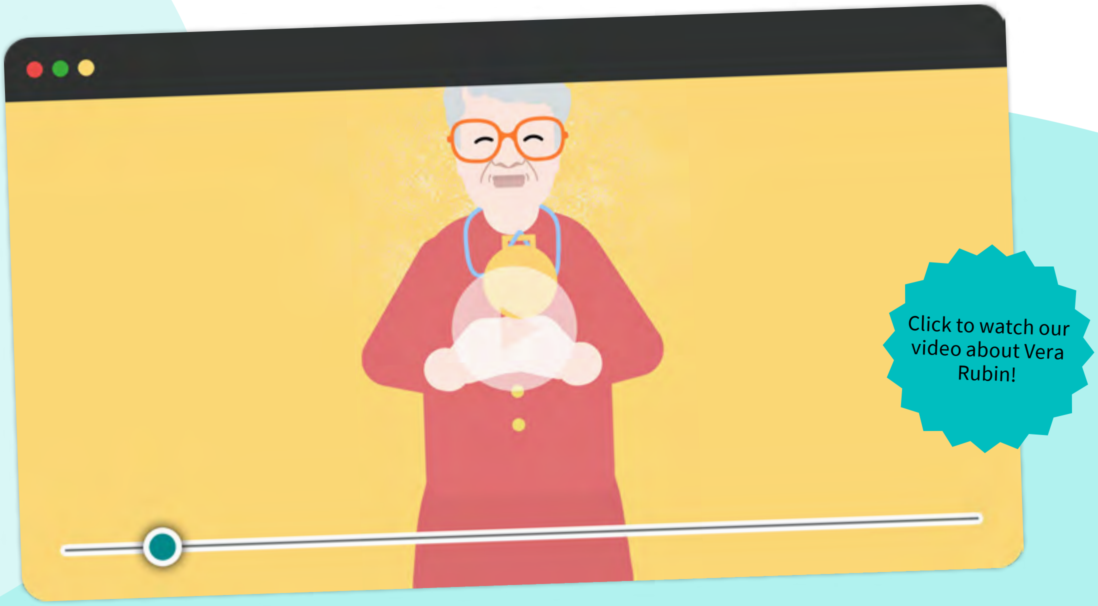
Who was Vera C. Rubin?

Dr. Vera C. Rubin was a pioneering American astronomer whose work profoundly changed the way we understand the Universe. Born in 1928, Rubin developed an early fascination with the night sky. As a young girl, she would stay up late, gazing through her bedroom window at the stars, and even built her own telescope with her father. This early interest blossomed into a lifelong passion for astronomy.

Vera Rubin's most significant contribution to science was her groundbreaking work on dark matter, (we call it dark because it does not emit light, and we still don't know what it's made of). In the 1970s, she and her colleague Kent Ford studied the rotation rates of galaxies using telescopes that included the 2.1-meter Telescope at Kitt Peak National Observatory. They discovered that stars at the edges of galaxies were moving just as fast as those nearer the center, a phenomenon that couldn't be explained on the basis of the visible matter alone. This led to the revolutionary conclusion that a large portion of the Universe is made up of dark matter, an invisible substance that interacts with the matter we can observe only by gravity. By providing the first convincing evidence of the existence of dark matter, Rubin influenced the creation of a whole new subfield of astrophysics.

Despite her monumental discoveries, Rubin faced numerous challenges as a woman in a predominantly male field. She often found herself the only woman in her classes and professional settings. Her applications to prestigious graduate programs were sometimes rejected simply because of her gender. But Rubin's curiosity and passion for the cosmos drove her to persevere.

Throughout her career, Rubin was also an advocate for women in science. She worked hard to support and mentor young female astronomers, breaking down barriers and encouraging them to pursue their dreams despite the obstacles. Her advocacy was as crucial as her scientific contributions, helping to pave the way for future generations of women in astrophysics and other sciences.



Vera Rubin's dual legacy is her transformative research confirming the existence of dark matter and her relentless push for gender equality in science. Her life and work continue to inspire scientists and advocates for equality, and we're proud to honor her with the name Vera C. Rubin Observatory.

Read about Vera Rubin's life and work in her own words in [The Annual Review of Astronomy and Astrophysics.]

Pinhole LSST Camera image of a photo of Vera Rubin, courtesy of the Carnegie Institution for Science. Credit: Carnegie Institution for Science/LSST Camera Team/SLAC National Accelerator Laboratory/Rubin Observatory

Did you know?

Dr. Vera C. Rubin will be featured on a U.S. quarter in 2025 as part of the American Women Quarters Program. This initiative, which began in 2022, honors women who have made significant contributions to American history. Rubin's coin will be released alongside quarters celebrating other notable figures such as Ida B. Wells and Althea Gibson.

Observatory Site

NSF–DOE Vera C. Rubin Observatory is part of a global effort to unravel the mysteries of the Universe, with contributions from scientific institutions worldwide. Its physical location is in Chile, which hosts more than 40% of the world's astronomical infrastructure.

Rubin in Chile

Rubin Observatory is privileged to operate and conduct groundbreaking research on Cerro Pachón, a mountain in Chile's Andes range. Northern Chile offers some of the clearest, driest and darkest skies in the world — ideal conditions for studying the light coming from space and addressing some of humanity's biggest questions about the Universe.

Credit: RubinObs/NSF/AURA/A. Alexov

Cerro Pachón

Rubin Observatory is located on Cerro Pachón, a mountain it shares with Gemini South telescope and the Southern Astrophysical Research (SOAR) Telescope. NSF Cerro Tololo Inter-American Observatory operates SOAR, as well as the Victor M. Blanco 4-meter Telescope on neighboring Cerro Tololo. All these facilities are on land managed by the Association of Universities for Research in Astronomy (AURA) and collectively make up AURA Observatories in Chile.

Cerro Pachón is about 100 kilometers (60 miles) inland from La Serena, home of the Rubin Observatory base facility on the AURA Recinto (an office and housing complex).

In addition to its scientific importance, Cerro Pachón is also ecologically impressive. Its mountainous terrain is home to a wide range of plant and animal species uniquely adapted to the high-altitude and desert climate. Cacti, shrubs, and wildflowers frequent the landscape. Cerro Pachón also hosts foxes and viscachas, which roam the hillsides, as well as lizards, snakes, spiders, scorpions, and a range of insects. Overhead, Andean condors soar through the sky.

Cerro Pachón is located in a seismically active region, where small earthquakes occur regularly. For this reason, Rubin's Simonyi Survey telescope is securely mounted on a massive concrete pier embedded in the stable foundational bedrock of the mountain. This pier is isolated from the observatory building to minimize the effects of any vibrations caused by seismic activity, as well as vibrations caused by other factors like equipment or wind.

Credit: NOIRLab/NSF/AURA/T. Matsopoulos

Site Selection

Selecting Rubin Observatory's site on Cerro Pachón was a three-year process that began in 2003. The selection was driven by key factors, such as the number of clear nights per year, seasonal weather patterns, and stability of the local atmosphere (known as the "seeing").

Another significant benefit of the site was the availability of supporting infrastructure and telecommunications services needed to support the 20 terabytes of data that the observatory will produce each night. Cerro Pachón is also relatively close to a shipping port, which would enable delivery of major telescope components like the mirrors and camera.

View of Rubin Observatory at sunset in May 2024, on Cerro Pachón in Chile. Olivier Bonin/SLAC National Accelerator Laboratory

Rubin Observatory received private funding in 2007 that allowed the fabrication of the combined primary/tertiary mirror (M1M3), the construction of the secondary mirror (M2) glass, and the initial preparation of the site on Cerro Pachón.

The project received federal funding for construction from the National Science Foundation and the U.S. Department of Energy's Office of Science in 2014, and Rubin's construction kickoff was officially marked with a First Stone ceremony — a Chilean tradition — on 14 April 2015. This milestone event was attended by Chilean President Michelle Bachelet, U.S. Ambassador to Chile Michael A. Hammer, NSF Director France Cordova, and Charles Simonyi, among other dignitaries.

Science Overview

NSF–DOE Vera C. Rubin Observatory and the Legacy Survey of Space and Time (LSST) will revolutionize the way we explore the cosmos. Rubin will create the ultimate movie of the night sky, repeatedly scanning the sky for a decade to create an ultra-wide, ultra-high-definition, time-lapse record of our Universe across space and over time. The resulting dataset will be the largest ever amassed for optical astronomy. Rubin data will be used by astronomers and astrophysicists around the world to make countless discoveries. Instead of applying for telescope time to study specific objects, scientists using Rubin Observatory data will have access to an all-purpose dataset of about 40 billion stars, galaxies, and Solar System objects — each observed over 800 times — to study as they choose. This is the first time this much astronomical data will be available to so many people, and there's no telling what discoveries we will make using Rubin Observatory.

Rubin is a powerful new scientific tool to answer many science questions, such as: How did the Milky way form? What is 95% of the Universe made of? What will a full inventory of Solar System objects reveal? What will we learn from watching millions of changes in the night sky over 10 years? What discoveries will scientists make that we don't know to anticipate yet?

These questions and the myriad of others that Rubin Observatory was designed to address can be classified into four key science areas:

- Understanding the nature of dark matter and dark energy
- Creating an inventory of the Solar System
- Mapping the Milky Way
- Exploring the transient sky

Rubin will create the ultimate movie of the night sky, repeatedly scanning the sky for a decade to create an ultra-wide, ultra-high-definition, time-lapse record of our Universe across space and over time. The resulting dataset will be the largest ever amassed for optical astronomy.

The Legacy Survey of Space and Time (LSST)

Rubin Observatory will conduct an unparalleled decade-long survey of the entire Southern hemisphere sky called the Legacy Survey of Space and Time (LSST). In 10 years, Rubin Observatory will generate more data than everything that's ever been written in any language in human history, about 60 petabytes. Each night, Rubin will scan the sky, capturing images with the LSST Camera, the largest camera ever built. Each image will cover about 10 square degrees of sky, an area so big it could contain 45 full moons. Every three to four nights, Rubin will cover the entire visible southern hemisphere sky using different color filters spanning wavelengths of light from the near-ultraviolet to the near-infrared. Over the course of 10 years, Rubin will build the most detailed time-lapse view of the cosmos ever generated.

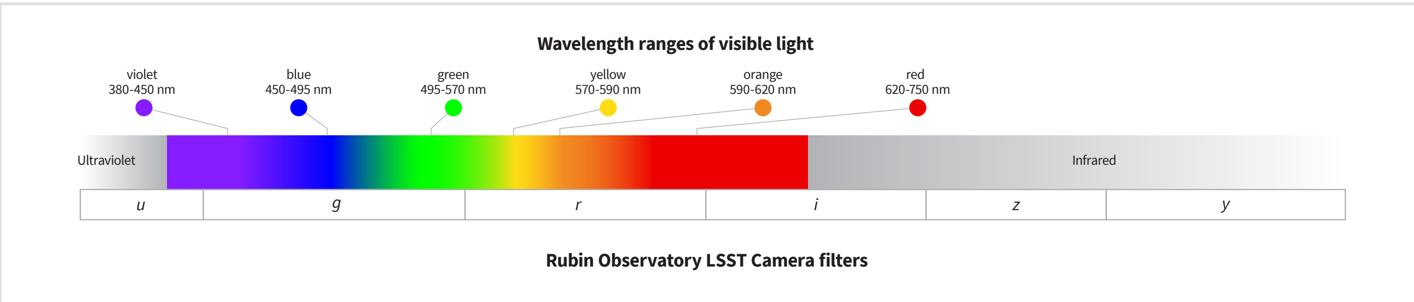
Rubin Observatory will be a game-changer for astronomy and astrophysics — bringing a plethora of objects and phenomena into view for the first time. With its incredible light-collecting power and highly sensitive camera, Rubin Observatory's 10-year survey will produce trillions of measurements of billions of objects.

Rubin Observatory at night. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/B. Quint

Colors of the Universe

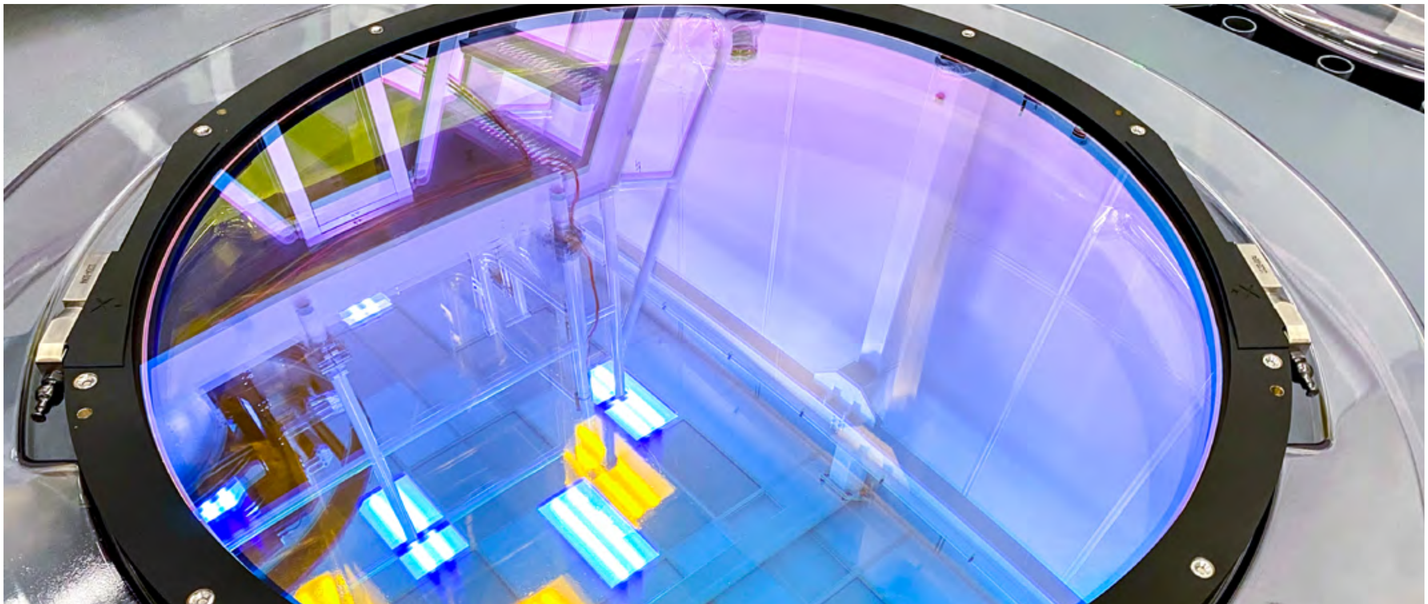
Different wavelengths of light convey different types of information about the physical processes happening in the Universe, and scientists use filters to capture the appropriate color of light depending on the information they need about the cosmos.

Rubin Observatory's LSST Camera is sensitive to wavelengths from 320 to 1050 nanometers. When taking an image of the sky, the LSST Camera uses one of six different colored filters, labeled with the letters *u*, *g*, *r*, *i*, *z*, and *y*. Each filter lets through a specific range of colors — from high-energy ultraviolet (*u*), through the visible colors detectable by the human eye (*g*, *r*), all the way into the near-infrared (*i*, *z*, *y*).



This image compares the wavelength ranges of visible light in nanometers to the Rubin Observatory camera filters. The Rubin filters transmit light from ultraviolet to infrared wavelengths (330 to 1060 nanometers). Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Each filter helps probe different scientific areas of interest, from exploring the nature of young and hot blue stars in the ultraviolet to measuring faint and distant red galaxies in the infrared. The resulting data captured by LSST Camera record a myriad of information about each object in the image at the particular wavelength range associated with the filter in use at the time of observation.



The *r*-band camera filter transmits longer wavelengths of visible light as well as some infrared wavelengths. Credit: Travis Lange/SLAC National Accelerator Laboratory

Key Science Areas

Rubin Observatory will address many science questions with one survey: What is the mysterious dark energy that is driving the acceleration of the cosmic expansion? What is dark matter and how do its properties affect the formation of stars, galaxies, and larger structures? How did the Milky Way form, and how has it merged with smaller galaxies over cosmic time? How did our Solar System form and evolve, and what can we learn from a full inventory of Solar System objects? How and why do stars pulsate, erupt, collapse, and explode? What new and exotic phenomena exist in the Universe that have not yet been discovered?

With such a rich dataset, it's impossible to list all the potential discoveries that Rubin Observatory data will enable. However, we list below a few that highlight details about the telescope — such as size, speed, or camera sensitivity — which were developed to maximize scientific discovery in these four science areas.

- Understanding the Nature of Dark Matter and Dark Energy
- Creating an Inventory of the Solar System
- Mapping the Milky Way
- Exploring the Changing Sky

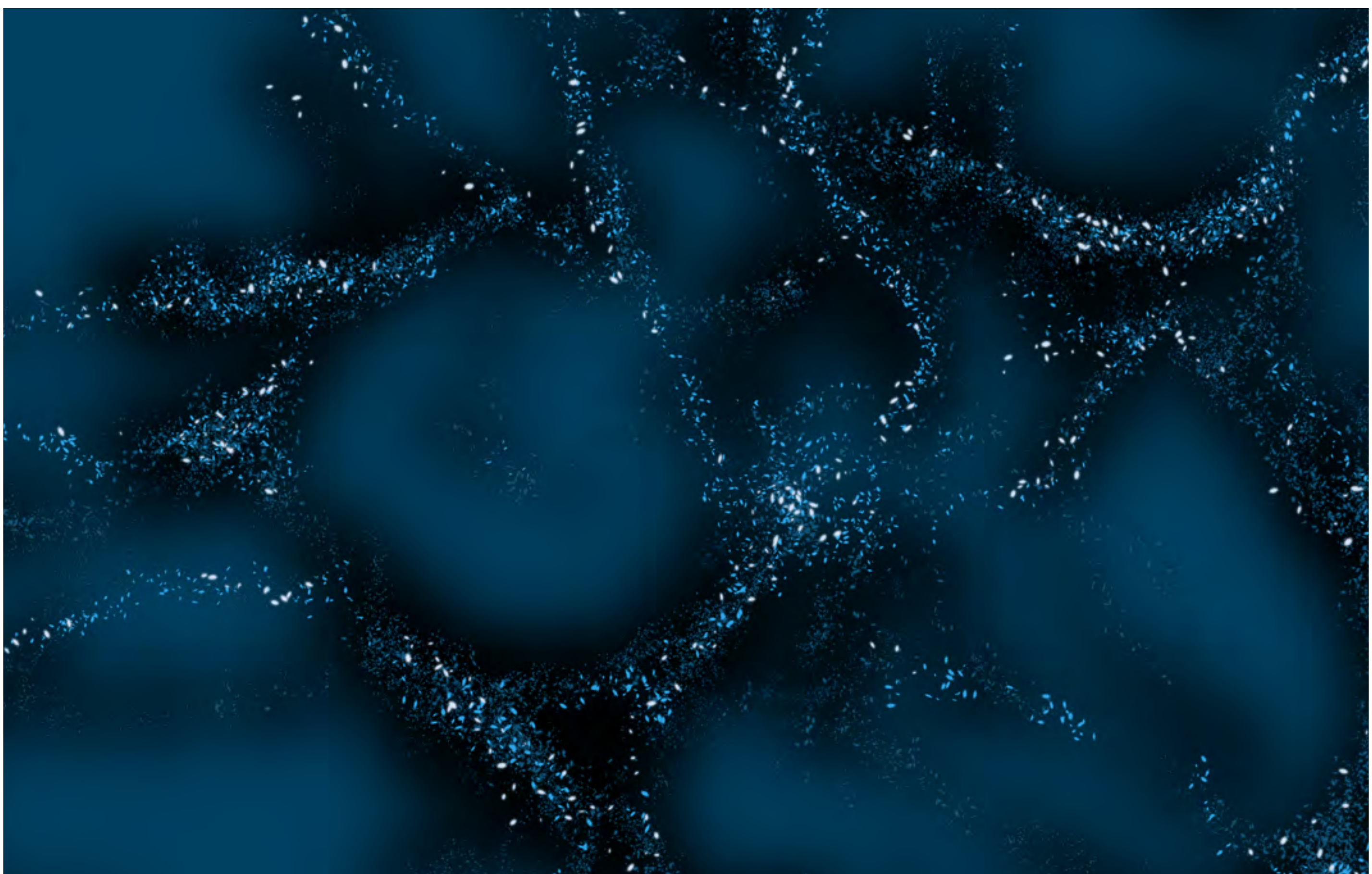
Understanding the Nature of Dark Matter and Dark Energy

Everything we know — galaxies, stars, planets, our families and friends — makes up just 5% of the Universe. The remaining 95% is made up of mysterious invisible components called dark energy (68%) and dark matter (27%). What are these, and how do they influence the structure and evolution of the Universe?

Rubin Observatory's wide field of view combined with its ability to detect faint and distant objects will help scientists explore the nature of dark matter and dark energy — on large and small scales — using a variety of methods. Rubin may even produce new evidence to support alternative explanations for the phenomena we observe in our Universe beyond the most common theories of dark matter and dark energy.

Some of the questions Rubin will enable us to address about dark matter and dark energy are:

- How is matter, including dark matter, distributed throughout the Universe? How has that distribution changed over time?
- How does dark matter affect how galaxies evolve?
- What is dark energy and how does it cause widely separated galaxies to move apart faster and faster?
- How have the largest-scale structures in the Universe like galaxy clusters grown over time?



Representation of dark matter. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Creating an Inventory of the Solar System

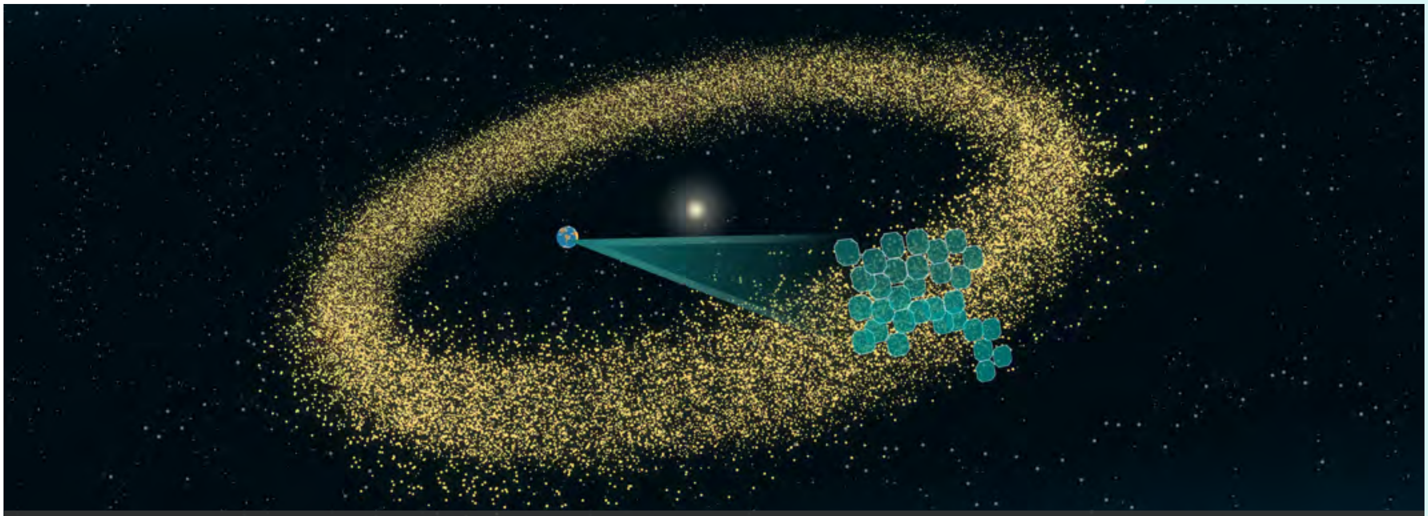
There is a huge, unknowable, number of planetary systems spread throughout the cosmos, but there is only one that scientists can study in exquisite detail — ours. Scientists have found about a million asteroids and comets so far, but they believe there are millions more distributed among and beyond the planets of our Solar System. However, these objects are hard to find — they're small, far away, and usually dark.

Rubin Observatory's deep and wide survey is expected to uncover four times more Solar System objects than we currently know of. Using sophisticated software, scientists will be able to identify and track millions of Solar System objects, mapping their orbits and physical properties like size or composition over time. Rubin will capture hundreds of observations of many of these objects in multiple wavelengths and provide crucial color information that will help scientists understand what these objects are made of. This vast, unprecedented dataset will help scientists understand how the Solar System came to look the way it does — and by studying these objects in our own Solar System, scientists can piece together the early processes that shape other planetary systems.

In just one year, Rubin Observatory will have detected more asteroids than all other previous telescopes combined. And over 10 years, Rubin will help us discover four times more asteroids in our Solar System than we currently know about.

Among the Solar System questions scientists hope to answer with Rubin data are:

- How did our Solar System form, and how has it evolved?
- What chemical elements were present in the early Solar System? Where were they, and where are they now?
- How many objects are there that could pose a threat to Earth, and where are they?
- Is there an undiscovered planet beyond Neptune?



Several of Rubin Observatory's observation footprints are projected upon some of the millions of asteroids that Rubin will detect. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Mapping the Milky Way

Our home galaxy is a typical spiral galaxy that can be used for the general study of the growth and development of galaxies throughout the Universe. Rubin Observatory's massive 10-year dataset will enable us to catalog the stellar populations within the Milky Way to a level of detail that hasn't been possible before. With these data, scientists will be able to build a reliable map of the Milky Way that contains close to 1000 times the volume of previous surveys, documenting the colors and brightnesses of billions of stars.

Cataloging the stellar populations of the Milky Way as well as its companion galaxies will foster a deeper understanding of how our galaxy formed and evolved — and, by extension, how other galaxies have evolved throughout the Universe's history. Rubin Observatory's wide-field survey and detailed view will bring the remnant structures from past mergers with the Milky Way into view for the first time, allowing us to tell the story of our home galaxy better than ever before.

Some of the questions about our Milky Way scientists hope to answer with Rubin data are:

- How did the Milky Way form and how has it changed over time?
- What are the common properties of stars close to the Sun? What can they tell us about how our own Solar System formed?
- How have other galaxies formed and evolved throughout the Universe's history?

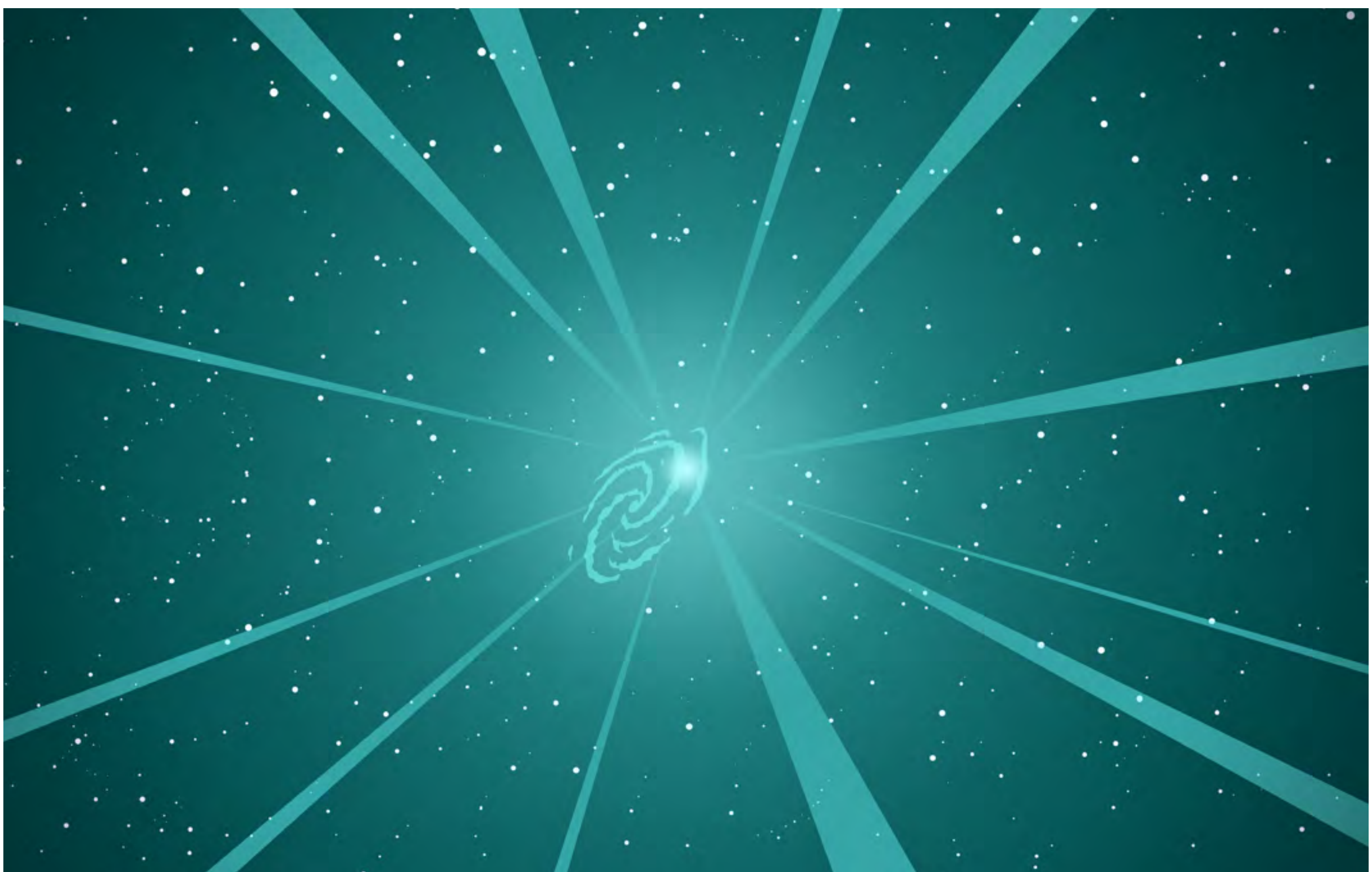
Representation of the Milky Way. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Exploring the Changing Sky

Rubin Observatory's unique movie will bring the night sky to life, yielding a treasure trove of discoveries: asteroids and comets, pulsating stars, and supernova explosions.

With its huge, repeated scans of the entire southern hemisphere sky, Rubin Observatory will identify millions of changes, or "transients," in the sky on any given night. Examples of transients include pulsating or exploding stars, actively feeding black holes, or mergers of compact objects like neutron stars. Rubin's immense datastream will enable scientists to study the origins and behaviors of transients, providing new understanding of star evolution and the explosive and evolving processes in the Universe.

Rubin Observatory is capable of sending out about 10 million alerts per night — every one indicates a change in the Universe! With sophisticated processing software that compares new images to a template made from previous images and identifies changes in near real time, scientists will have a greater chance of discovering rare and exotic transient objects throughout the Universe and gaining new insight into known kinds of transient events. And with its capacity to provide near-real-time, world-public alerts to the community, Rubin Observatory will make sure other telescopes can get in on the action with additional dedicated observations in complementary wavelengths of light.



Representation of a supernova. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

In addition to the research made possible by Rubin's alert stream, other studies of the transient and variable Universe will benefit from the repeated photometric measurements within Rubin's annual data releases. Over 10 years, with each part of the sky carefully imaged about 800 times, changes on long and short timescales will be revealed. The lightcurves derived from these data releases will be a unique and valuable legacy to time-domain science.

Rubin Observatory and the LSST are poised to completely transform our understanding of the changing cosmos, revealing new populations and types of transient events that have remained hidden until now.

Among the questions scientists hope to answer about the changing sky with Rubin data are:

- Why do some objects in the Universe change over short time scales? What physics controls their behavior?
- What types of stars die in bright explosions? How do these explosions differ? How are they similar?
- What can stellar variability tell us about the extreme pressure and heat conditions at the cores of stars?
- What kinds of new objects and physics will we discover that have never been seen before?

Over 10 years, with each part of the sky carefully imaged about 800 times, changes on long and short timescales will be revealed.

Unexpected Unknowns

Beyond answering existing questions, Rubin's extensive 10-year survey has the potential to reveal entirely new mysteries, leading us to questions we haven't known to ask yet. There could be entirely new classes of objects, never-before-seen transients, phenomena that challenge existing theories and models, or discoveries that open up an entirely new field of research waiting to be revealed.

Every time we look at the Universe in a new way, we discover new things we never could have predicted. And now we will see more things than we ever have before.

Rubin Observatory/LSST Science Collaborations

History

The Rubin Observatory/LSST Science Collaborations are eight groups of scientists from around the world who have come together to study all kinds of different science using Rubin Observatory's Legacy Survey of Space and Time (LSST) — from closer objects in our own Solar System to the Milky Way and more distant stars, and from supernovae or black holes that change over weeks and months to bigger structures like galaxies that take billions of years to evolve. The science collaborations first formed in 2006 to help make the [science case] for why the U.S. Congress and other funders should support the construction of Rubin Observatory (then called the "Large Synoptic Survey Telescope"). All their work paid off — Rubin Observatory was recommended as a top priority for astronomy and astrophysics in the 2010 Decadal Survey, which led to funding commitments from NSF and DOE.

The science collaborations first formed in 2006 to help make the science case for why the US Congress and other funders should support the construction of Rubin Observatory (then called the "Large Synoptic Survey Telescope").

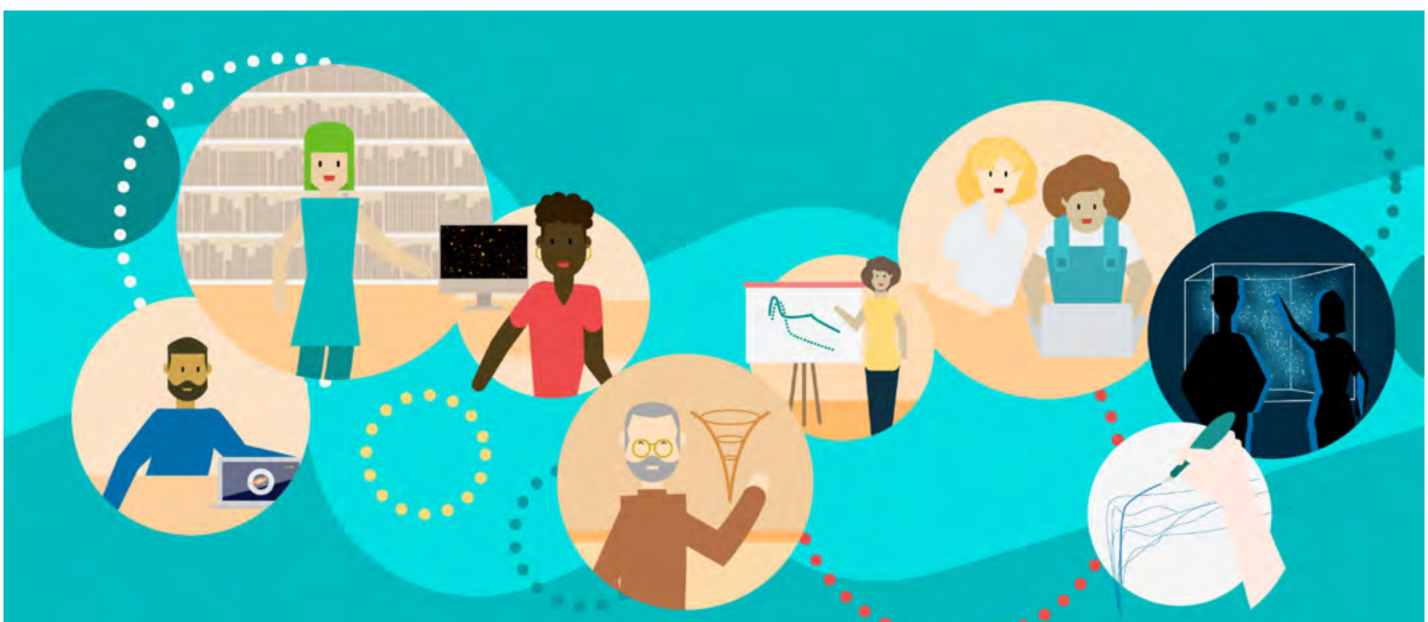


Illustration of scientists collaborating. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

The Science Collaborations Now

Since then, the Science Collaborations have grown in number — to several thousand scientists — and have evolved into self-organized groups focused around the different areas of science that Rubin Observatory was designed to study. The collaborations are more organized and official than just groups of scientists working together — each one has its own membership policies, rules for publications, codes of conduct, and other structures needed to get work done most effectively and to work together as a network to leverage each other's expertise. The Science Collaborations work closely with Rubin Observatory in a mutual partnership, providing feedback on the telescope design and the overall strategy for taking data. The Science Collaborations are kept closely in the loop about everything that happens at the observatory and can inform Rubin decisions to maximize the survey and observatory to ensure great science.

Scientists can belong to more than one Science Collaboration, and all the collaborations work together to make science with Rubin Observatory the best it can be. The collaborations will continue to play a crucial role in guiding the direction of science with Rubin Observatory throughout the 10-year LSST.

Active Galactic Nuclei Science Collaboration

Dark Energy Science Collaboration

Galaxies Science Collaboration

Informatics and Statistics Science Collaboration

Strong Lensing Science Collaboration

Stars, Milky Way, and Local Volume Science Collaboration

Solar System Science Collaboration

Transients and Variable Stars Science Collaboration

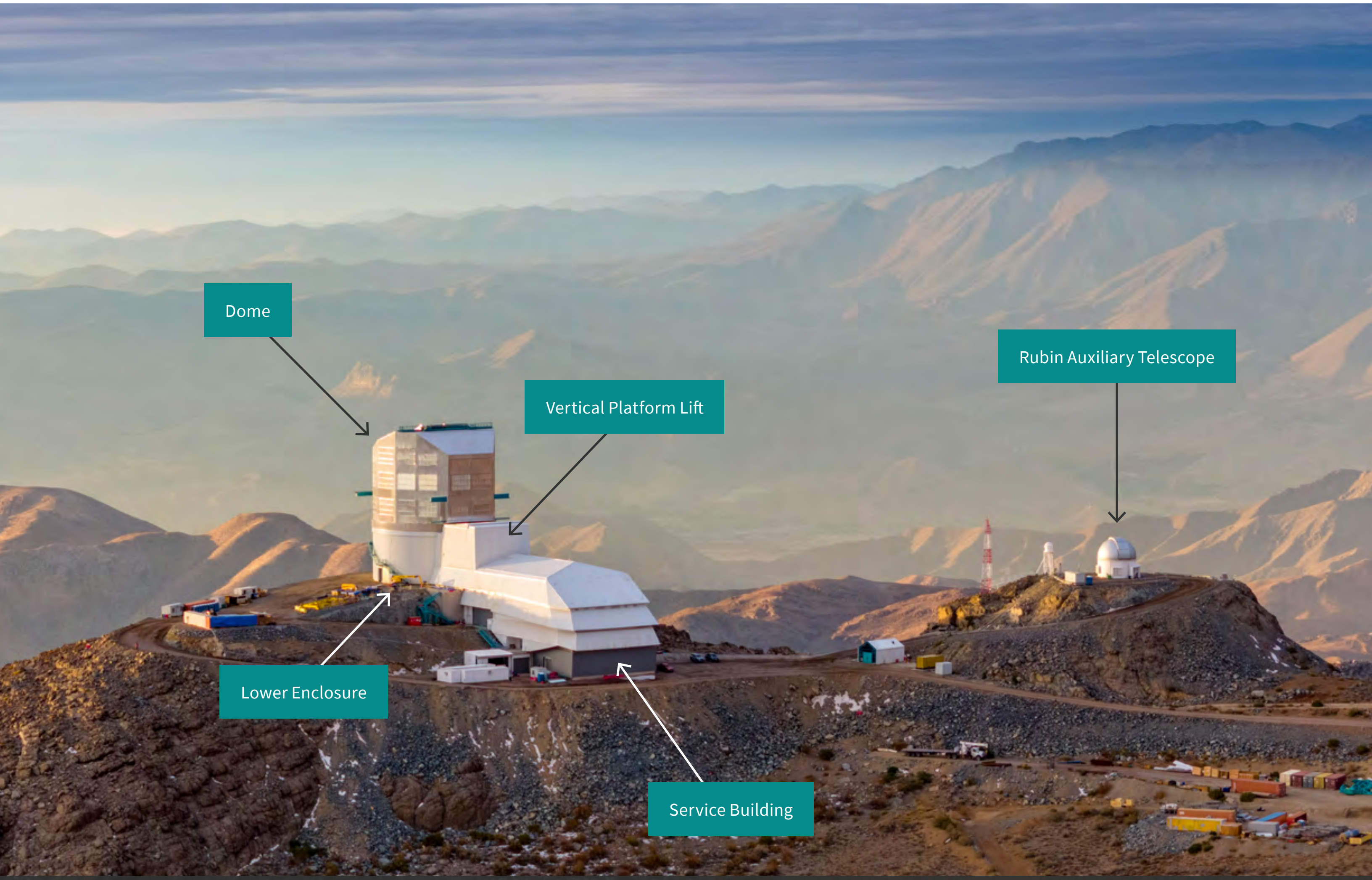
In-kind Contributors

Organizations and individuals around the world are providing a wide variety of in-kind contributions to Rubin Observatory (including time and effort, software tools, telescope time, computing resources and other infrastructure) in exchange for access to Rubin data during the two-year proprietary period before it becomes world-public. As of 2024, Rubin has received 153 formal in-kind contributions from 43 individual teams across 28 countries.

Summit Facility

The NSF–DOE Vera C. Rubin Observatory summit facility on Cerro Pachón was designed by [Arcadis Chile] and constructed by [Besalco Construction]. The building consists of the telescope pier (the structural support base for the telescope mount), a lower enclosure that supports the rotating dome, and an attached 3000-square-meter (32,000-square-foot) service and operations building. A separate enclosure nearby houses the [1.2-meter Rubin Observatory Auxiliary Telescope.]

The placement of Rubin Observatory's facility takes advantage of the topography of Cerro Pachón's summit. The domed telescope enclosure sits high enough that the telescope is above the local turbulent layer caused by warm air rising from the ground and mixing with cooler air above. The service building rests on a slightly lower area farther to the southeast. The specific orientation of the summit facility was selected after extensive weather testing and a computational analysis of the site verified that it provided the best seeing environment — the least air disturbance — for the telescope. Studies of the natural rock at the site have shown that it is strong and erosion-resistant.



View of Rubin Observatory at sunset in May 2024, on Cerro Pachón in Chile. Credit: Olivier Bonin/SLAC National Accelerator Laboratory

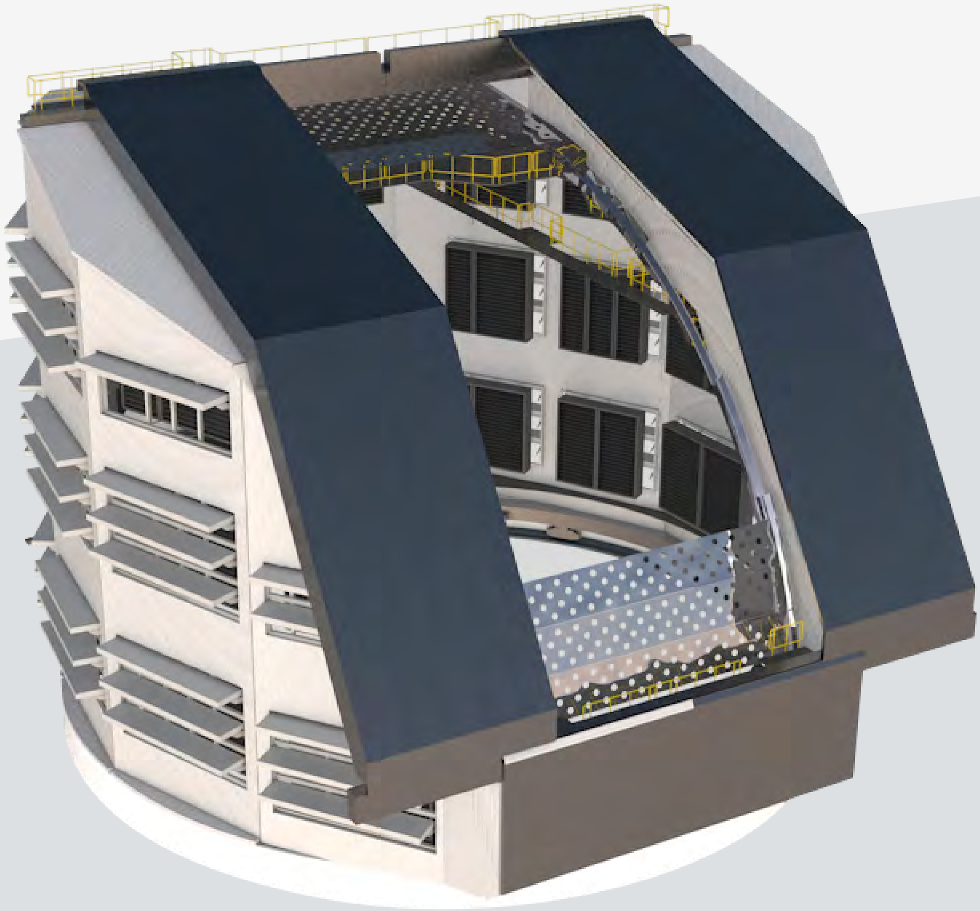
Dome

The dome of Rubin Observatory, designed and built by EIE Group, includes not only all the rotating components, but also its drive system, the control/interlock system, and the rail system for the wheeled carriages (called "bogies") that allow the dome to move along the track.

Because Rubin Observatory has a wide field of view, its optical system is particularly susceptible to stray light. The dome not only protects the Simonyi Survey Telescope from the environment but also provides critical shielding from excess light. All of the dome vents are covered with "light baffles," which block out light while still allowing air flow to equalize the temperature with that of the outside air.

The dome and the telescope operate separately, so while the dome moves more slowly than the telescope, it can crawl towards the next observing position while the telescope finishes taking an image and then catches up with the dome. This reduces the need for the 600-ton dome to move as fast as the telescope when moving to new observation areas.

The Rubin Observatory dome is finished with natural mill-finished aluminum sheeting, giving it a reflective silver appearance. This aluminum finish is better at reflecting sunlight during the day than a white surface, and it doesn't cool off as much at night — so there is less thermally turbulent air above the dome when night falls.

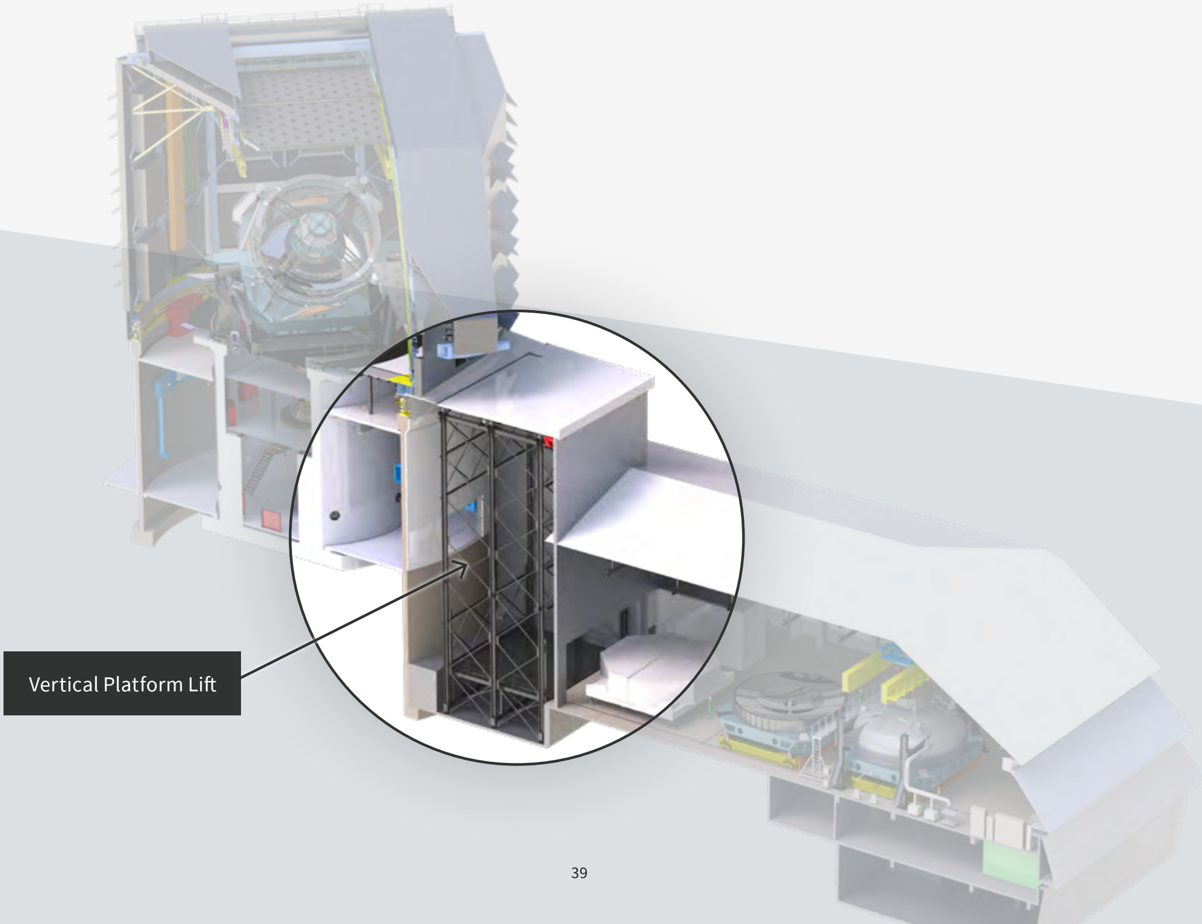


Vertical Platform Lift

Rubin Observatory's custom-built vertical platform lift, designed by PFlow Industries, is essential for moving heavy components of the telescope between the maintenance area and the telescope floor five levels above. The heaviest load to be raised and lowered with this lift is the combined weight of the Primary/Tertiary Mirror (M1M3), mirror cell, and transport cart — a total of almost 72.5 metric tons (80 tons). Above the lift is a movable section of roof which is pushed up by the lift carriage when it rises; this design minimizes the overall height of the lift structure and aids airflow over the building. When the lift is not in use, the roof is securely latched down to the building and the folding edge to meet weather protection and seismic requirements.

The platform lift allows the carriage to travel all the way up to the eighth level of the building: the telescope floor. The lift-up roof section weighs about 13.5 metric tons (15 tons), and rises 7.6 meters (25 feet) higher than the top of the shaft. In its highest position the lift carriage would obstruct the rotation of the telescope dome, which is why the roof wasn't installed permanently at this height — when the lift carriage is lowered, the roof section also lowers and locks securely in place clear of the rotating dome.

Because Cerro Pachón is such a seismically active area, the lift was designed to withstand earthquakes of up to 8.0 on the Richter scale. It will also be able to tolerate the strong winds that are common on the summit, although the lift is only used to move cargo when the weather allows for safe transport.

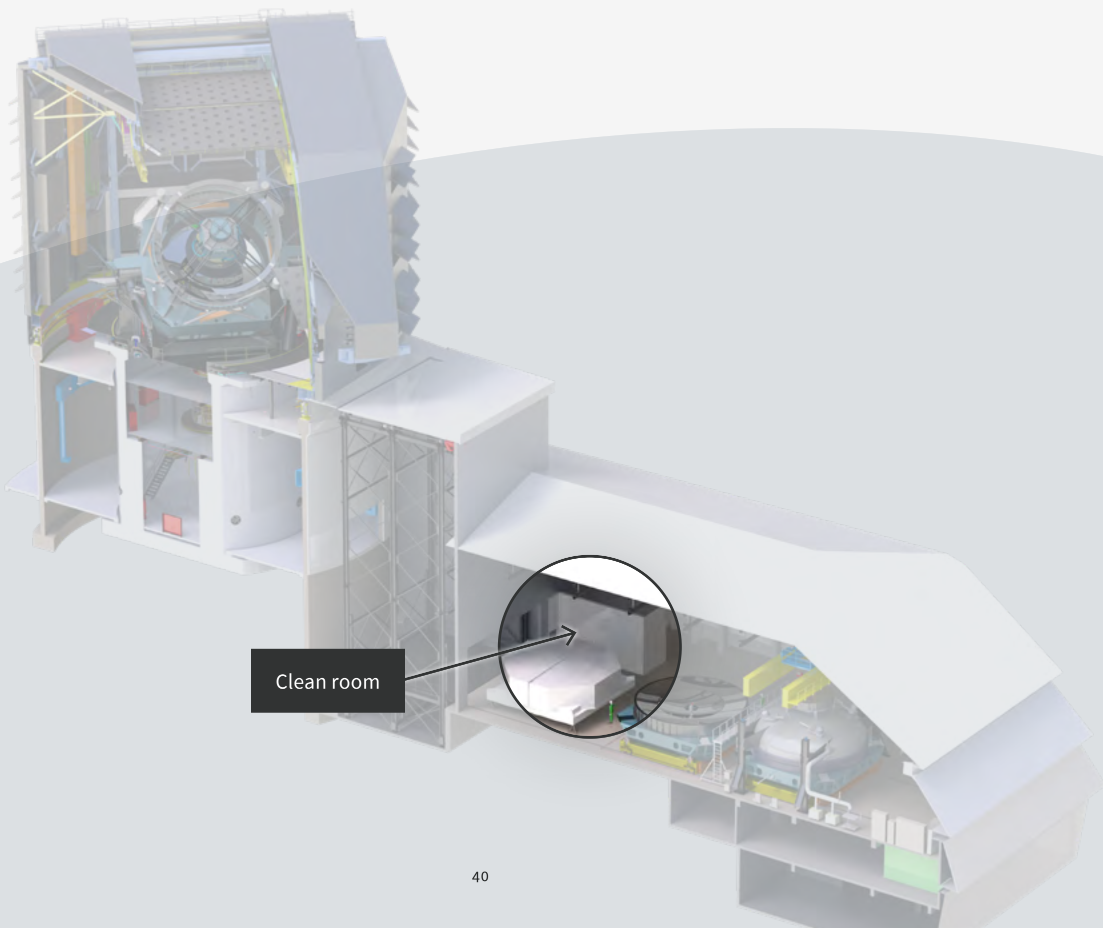


Clean Room

Rubin Observatory's service building has a dedicated clean room for any work related to the camera, because many of the camera components are so sensitive that they have to be protected from even the finest dust particles in the air. When mounted to the telescope, the camera's delicate components stay safe inside a vacuum-sealed cryostat, but if any parts are removed for maintenance or repairs they must be in a highly protected space. The camera clean room provides a dust-free environment, and only essential, trained staff can go inside.

Rubin Observatory's camera clean room (ISO class 7, U.S. federal standard 10,000), is located on the maintenance floor of the Rubin Observatory summit facility. It is the area where the Rubin Observatory LSST Camera was assembled and tested on a large support stand after arriving in Chile in 2024. This room will also be used if one of the detector rafts in the LSST Camera needs to be changed out during the 10-year Legacy Survey of Space and Time.

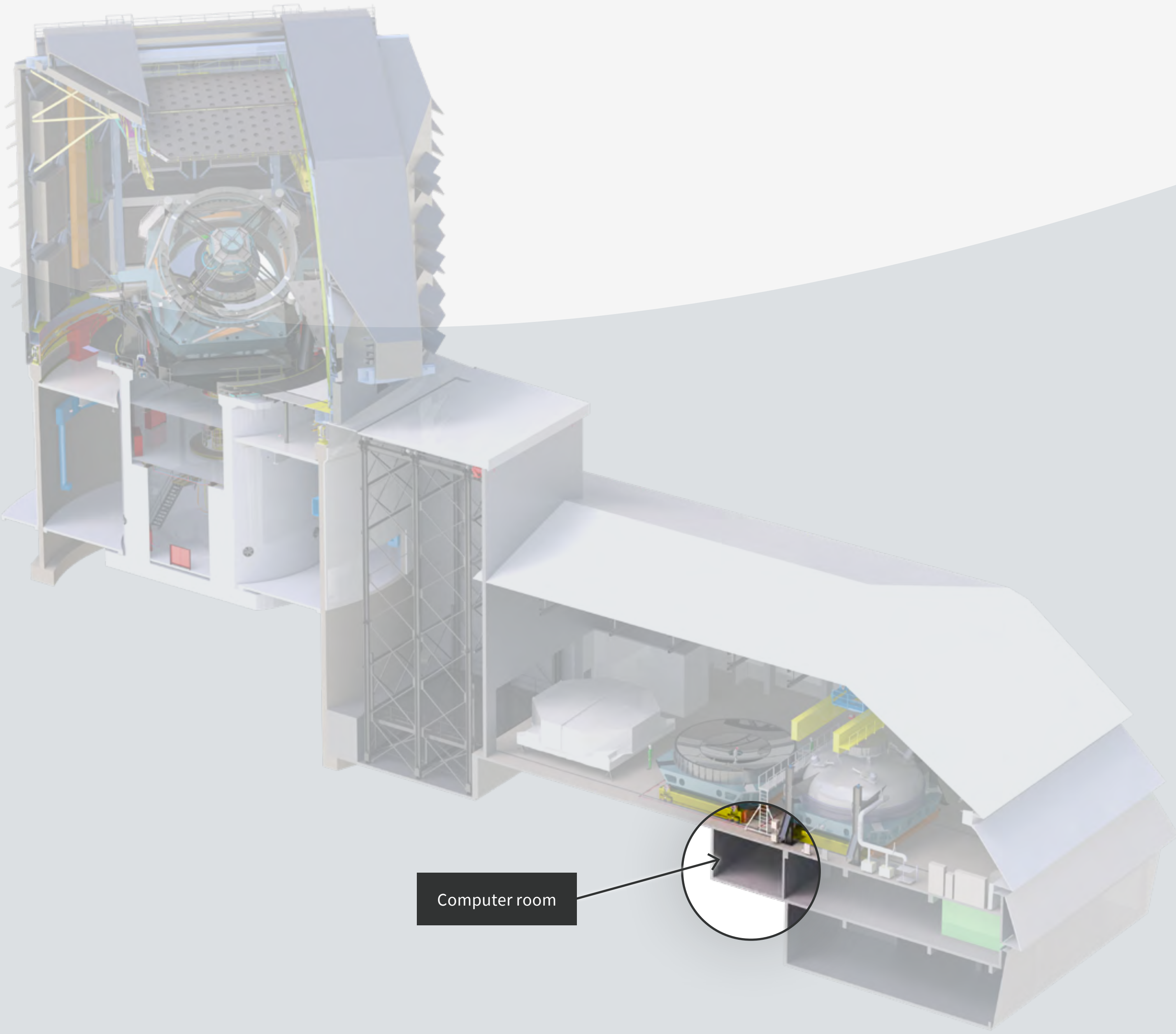
The camera white room — adjacent to the clean room — is ISO 8 (U.S. Federal standard 100,000). This room has been used for a number of activities, including running a test refrigeration system and assembling that system onto the Commissioning Camera, reinstalling the front lens assembly onto the LSST Camera, storing optical filters, and completing the system checkout before installing the camera on the telescope. The room will also be used when performing maintenance on the camera shutter and auto changer during operations.



Computer Room

The computer room at Rubin Observatory is 50 square meters (538 sq ft) with sufficient power and cooling for 14 racks. The Uninterruptible Power Supply (UPS) will last 8 hours in the case of loss of primary power. The raised floor can support an 816 kg (1800 lb) 48-unit rack. The room is designed for up to 65kW power draw. The temperature in this room is maintained between 18 and 22 degrees C (64-72 F), to keep the equipment cool.

There are 13 optical fiber cables (each with 24 strands) from the camera that run into the data acquisition systems housed here, and 100-Gbps network fibers travel from this room to the base of the mountain



and over international data networks to the US Data Facility using Dense Wave Division Multiplex (DWDM) protocols over redundant lines in case there is a disconnection somewhere. The camera and computer room can also store up to 30 days of data in case all communication is down.

The racks in this room are also populated with control computers for the many devices around the observatory. The telescope mount, mirrors, and instruments all have control processes running in the computer room. The engineering facility database, which records all events and messages on the mountain and sends data to the US Data Facility, is also housed here.

The telescope mount, mirrors, and instruments all have control processes running in the computer room.

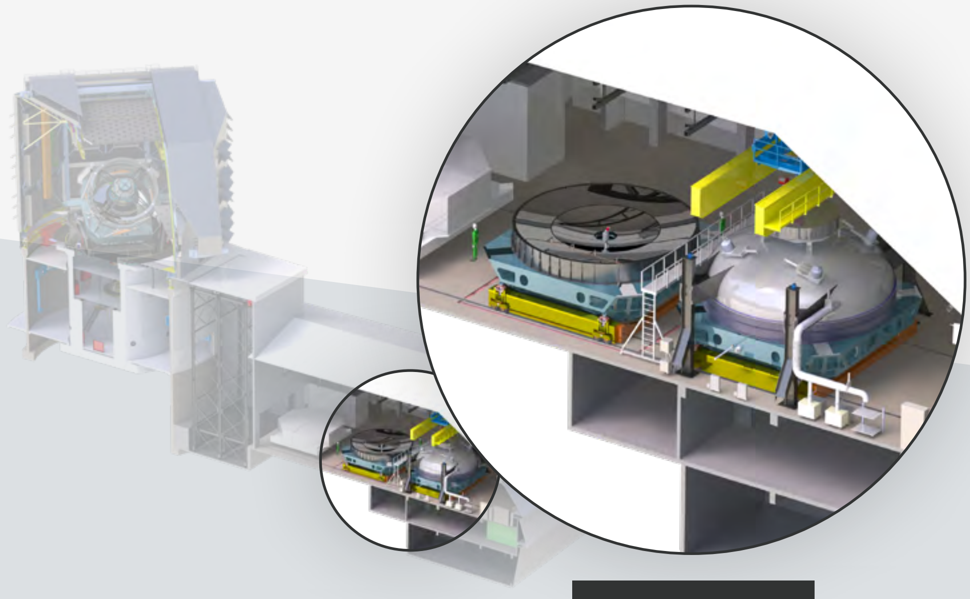
This equipment is part of the data acquisition system that moves data from the camera to a computer room on the summit. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA

Optical Coating Plant

The Rubin optical coating plant consists of the 128-metric-ton (116-ton) coating chamber and an adjacent washing station, both on the maintenance floor of the summit facility. The coating plant can precisely deposit both aluminum and silver as well as the necessary adhesion and protective layers on the glass optics to make them mirrors. Rubin's mirrors are coated with protected silver to maximize reflectivity in the wavelength ranges the LSST Camera is sensitive to, but other combinations with aluminum are possible in the future. The washing facility can also be used to strip coatings from the mirrors.

During Rubin Observatory's 10-year Legacy Survey of Space and Time, its mirrors will be exposed to the elements each night as the Simonyi Survey Telescope surveys the sky through the aperture of the observatory dome. Over time the mirrors will get dusty, and the mirror coatings may develop small blemishes that eventually affect performance. To ensure that Rubin Observatory continues to collect the sharpest possible images of the night sky, its mirrors will undergo regular cleaning on the telescope and — much less often — recoating. It's anticipated that the 8.4-meter combined primary/tertiary mirror will need to be recoated every two years, and the 3.5-meter secondary mirror every five years, during the 10-year survey. Having the coating plant onsite means the mirrors don't have to be transported down the mountain for stripping and coating, which reduces risk and minimizes telescope downtime.

The coating chamber was constructed by Von Ardenne in Deggendorf, Germany, and shipped to Chile in 2018. It was used to coat Rubin's secondary mirror in 2019, and the primary/tertiary mirror in 2024. It uses magnetron sputtering technology, a method that has proven successful with mirrors for other large telescopes including the twin Gemini telescopes and the European Southern Observatory's Very Large Telescope. There are two rings of magnetrons inside the coating chamber to accommodate the different mirror sizes and surface shapes.



Optical Coating Plant

Rubin Auxiliary Telescope

The 1.2-meter Rubin Auxiliary Telescope (AuxTel) sits on a hilltop a short distance from the main facility. The AuxTel was originally named Calypso, and it was located at NSF Kitt Peak National Observatory near Tucson, Arizona. After it was acquired from astrophysicist Edgar O. Smith, the telescope was removed from Kitt Peak, refurbished at Rubin headquarters by ACE Manufacturing, and sent to Chile.

The AuxTel improves the accuracy of Rubin Observatory data by measuring atmospheric transmission — how much light passes directly through Earth's atmosphere in a given area, as opposed to being absorbed or scattered by the different molecules and particles in the air. Atmospheric elements that affect the transmission of light coming from space change constantly, and include molecules like water, oxygen, and ozone, as well as aerosols like sea salt, dust, ash from volcanoes, and smoke from forest fires. The AuxTel determines and records how all those molecules and airborne particles in the atmosphere affect the light captured in Rubin Observatory images.

Each night, while Rubin Observatory surveys the sky, the AuxTel repeatedly observes a small set of bright stars. Inside the AuxTel a device called a spectrograph separates the light from each of these stars into its component wavelengths and records the results. By comparing the information recorded by the AuxTel with known information about these sample stars, we can measure how the atmosphere above Rubin Observatory distorts the light from these stars and, by extension, all of the light collected by the telescope. Later, when Rubin data are processed, we can use these measurements to apply the appropriate corrections for distortions to the collected light caused by the atmosphere.

Rubin Observatory and the Rubin Auxiliary Telescope (right). Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

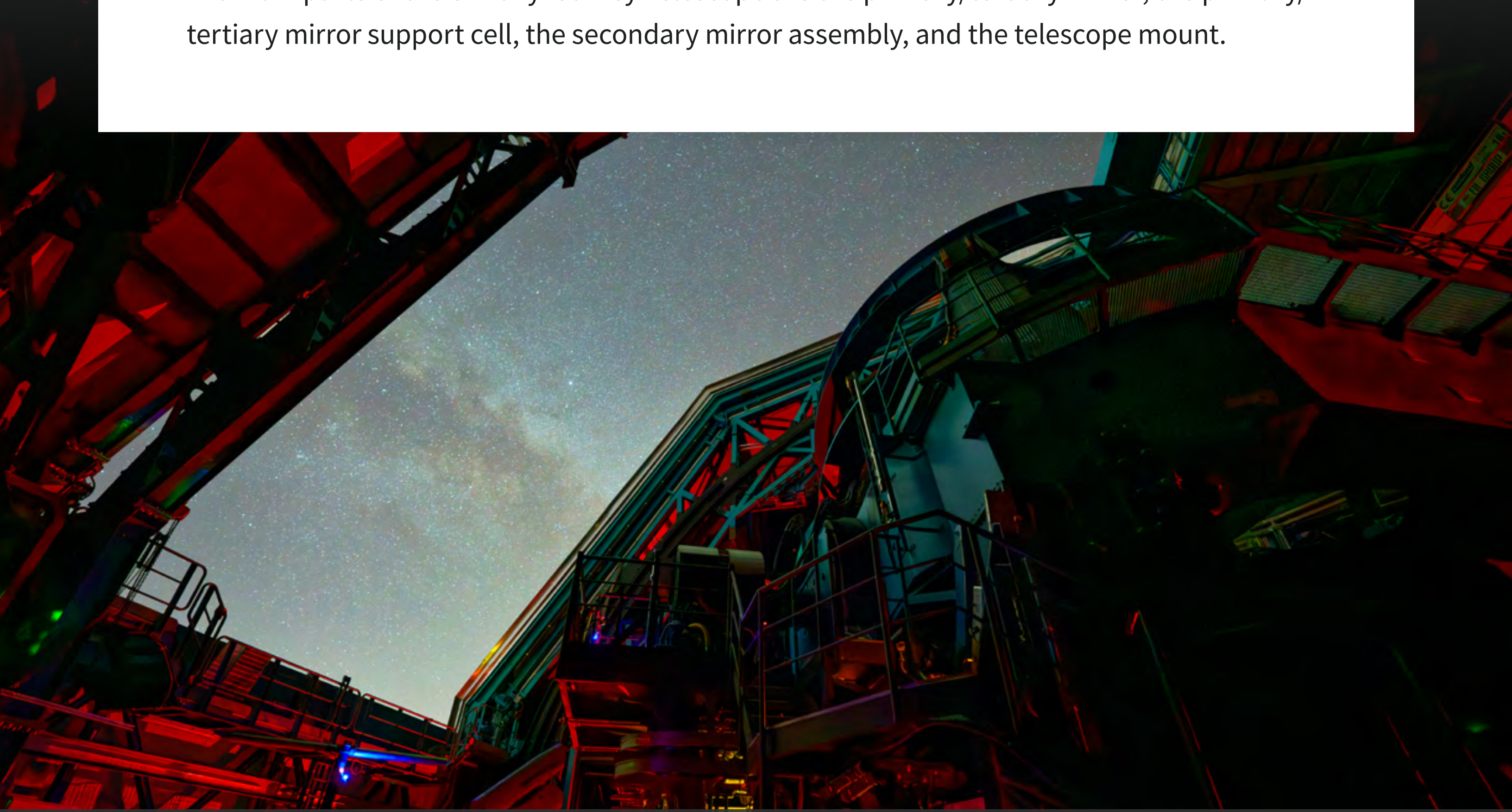
Simonyi Survey Telescope

The Simonyi Survey Telescope is the centerpiece of NSF–DOE Vera C. Rubin Observatory. The name of the telescope was revealed in a ceremony honoring the Simonyi family on 4 October 2024.

The telescope features the largest field of view of any large (greater than 6-meter) telescope, covering about 10 square degrees of the sky in a single exposure. This wide field allows it to survey large areas of the sky quickly, enabling the rapid discovery of transient events like supernova explosions and tracking of moving objects like asteroids.

The telescope's three-mirror design is unique in that two differently curved mirrors (the primary and tertiary) are combined on one monolithic glass substrate, and the 3.5-meter convex secondary mirror is mounted facing down and towards the primary/tertiary mirror. The secondary mirror has a hole in its center through which the LSST Camera is mounted. This novel optical design gives Rubin enormous light-collecting power in a compact structure that can be fast and nimble enough to cover the whole visible sky in just a few nights.

The main parts of the Simonyi Survey Telescope are the primary/tertiary mirror, the primary/tertiary mirror support cell, the secondary mirror assembly, and the telescope mount.



Credit: RubinObs/NSF/DOE/NOIRLab/SLAC/AURA/H. Stockebrand

Primary/Tertiary Mirror (M1M3)

Rubin’s 8.4-meter combined primary/tertiary mirror is like no other telescope mirror in the world. It consists of two differently-curved optical surfaces on a single substrate. Light reaches the outer optical surface (M1) first, reflects up to a 3.5-meter secondary mirror (M2), back down to the 5-meter inner surface (M3), and then up to the camera. An animation of the light path is available in this video.

Rubin’s 8.4-meter combined primary/tertiary mirror, often referred to as M1M3, was fabricated over a period of approximately seven years at the Richard F. Caris Mirror Lab at the University of Arizona. The “High Fire” event, in which the glass was cast, took place in March 2008. The mirror was completed in April 2015 after years of grinding and polishing brought the surfaces to the required specifications. It was shipped to Chile in May 2019 and stored on the summit while construction continued on the telescope mount. The mirror was coated in April 2024 and installed on the Simonyi Survey Telescope in September 2024.

Team members celebrate the successful casting of the telescope’s 27.5-foot-diameter mirror blank in August 2008. Credit: Howard Lester/NOIRLab/ Vera C. Rubin Observatory/ NSF/ AURA

Chunks of glass are loaded during fabrication of Rubin Observatory’s 8.4-meter combined primary/tertiary mirror. Credit: Ray Bertram/Rubin Observatory/NSF/AURA

Rubin Observatory’s 8.4-meter combined primary/tertiary mirror with its protected silver coating, applied in April 2024. Credit: Rubin Observatory/NSF/AURA

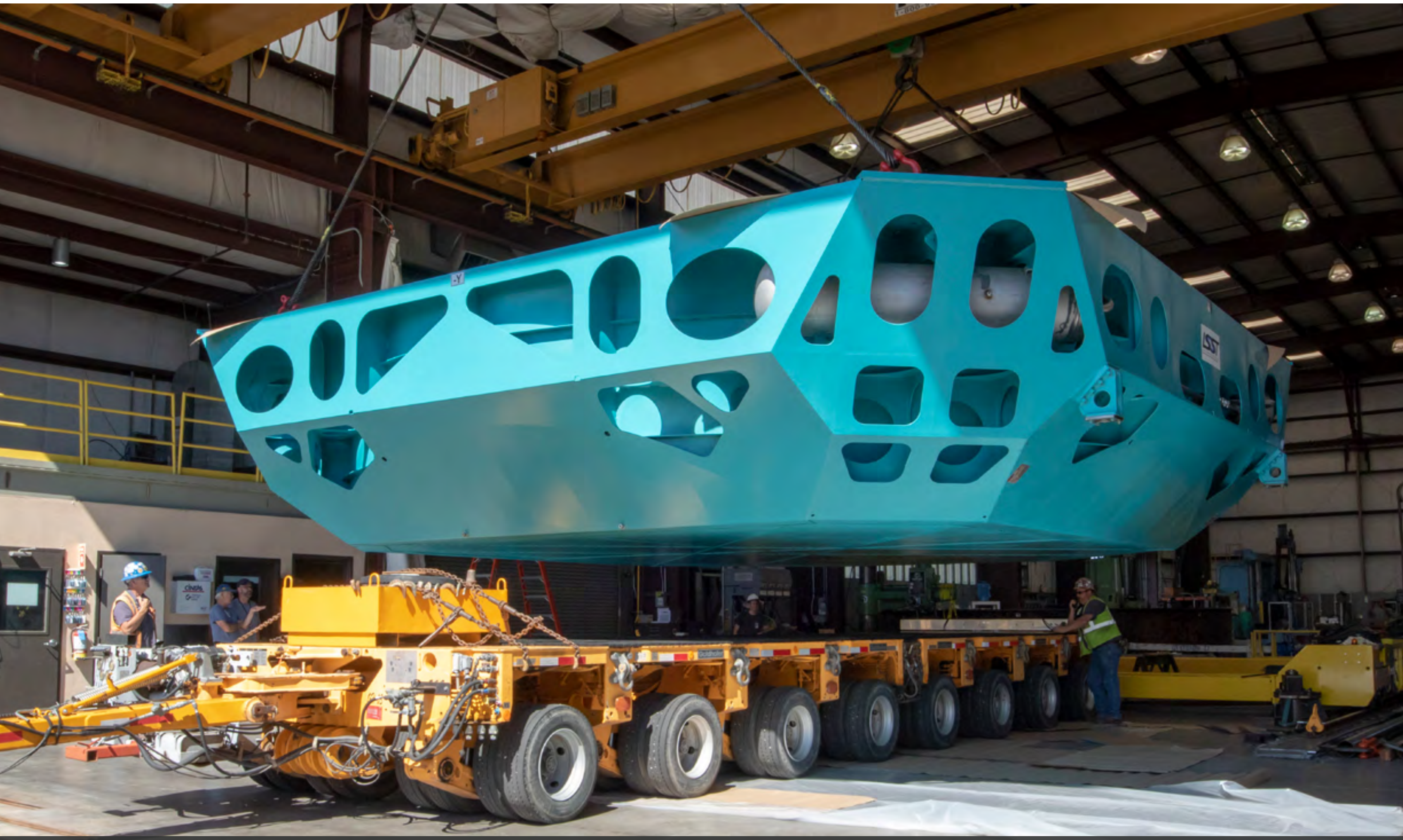
Primary/Tertiary (M1M3) Mirror Cell

The M1M3 mirror cell is the structure that supports Rubin's 8-4-meter primary/tertiary mirror and houses all the utilities needed to control the precise mirror support and temperature condition of the glass. The M1M3 Cell was designed in-house by Rubin Observatory's engineering department.

The cell provides gravity support, figure correction, and thermal compensation to the mirror as it changes orientation on the telescope and as the operational temperatures constantly change. When the M1M3 mirror is coated, the lower half of the coating chamber is removed, and the M1M3 cell is used as the lower vacuum chamber vessel. This use-case greatly impacted the structural design of the cell.

The main 9 m × 9 m × 2 m (30 ft × 30 ft × 7 ft) steel structure of the cell was fabricated at CAID Industries in Tucson, AZ, while the mechanical, electrical, and electronics components were fabricated by NSF NOIRLab in Tucson, AZ. After the cell's completion in 2018, it was integrated with the M1M3 mirror for optical testing at the Richard F. Caris Mirror Lab at the University of Arizona.

The M1M3 cell arrived on Cerro Pachón in July, 2019. It was installed on the Simonyi Survey Telescope with the glass mirror in October 2024.



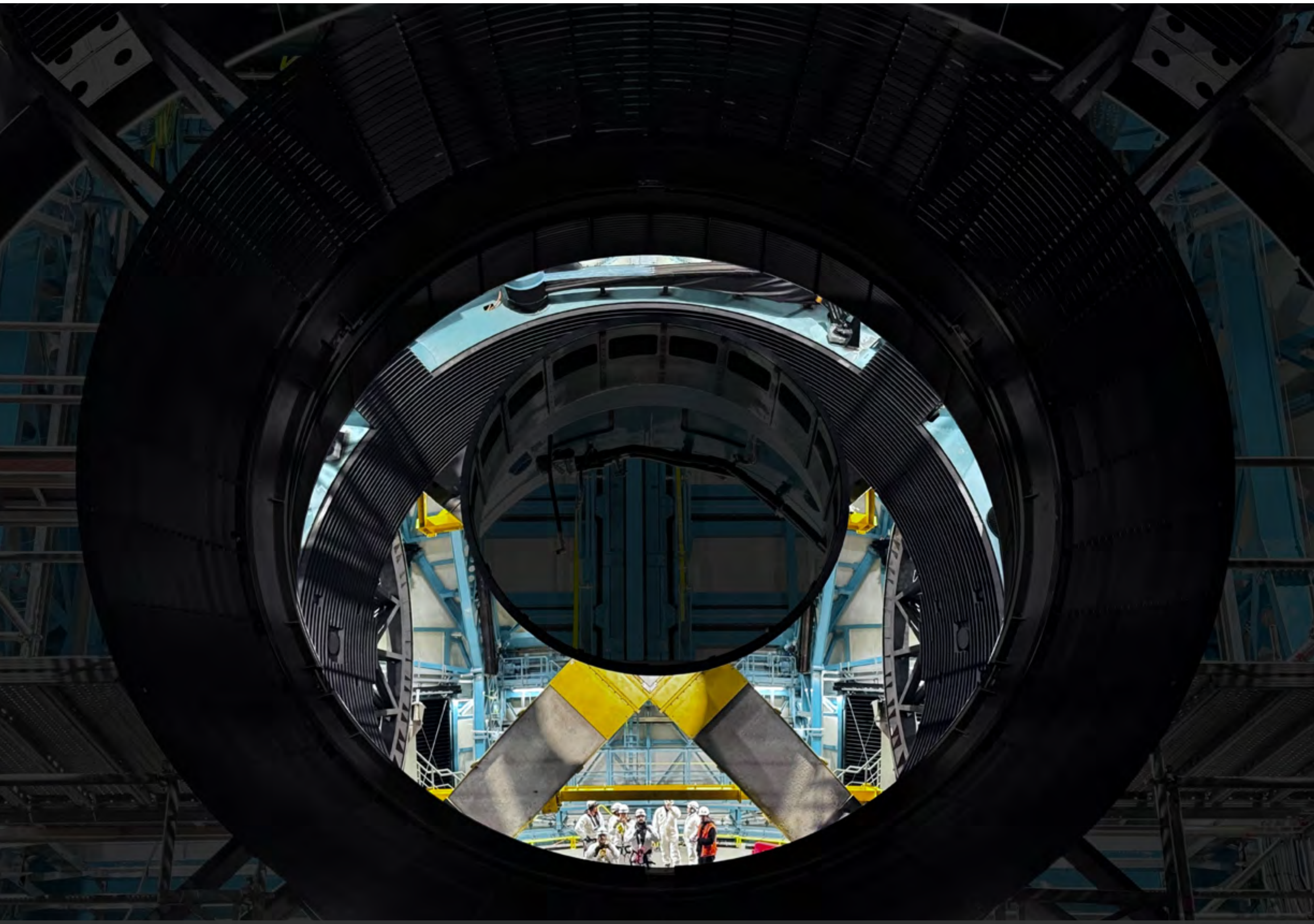
Rubin Observatory's 8.4-meter combined primary/tertiary mirror cell is loaded for transport. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA

Secondary Mirror (M2)

At 3.5 meters in diameter, Rubin's secondary mirror (M2) is one of the largest convex mirrors ever made. The 10-centimeter-thick monolithic mirror blank was manufactured by Corning Advanced Optics in Canton, New York, using Corning® ULE® Glass (Ultra-Low Expansion Glass) by fusing smaller sections of glass together.

The secondary mirror was polished and finished at L3Harris Technologies in Rochester, New York. L3Harris used novel measurement techniques in the polishing process to manage such a large precision convex surface. L3Harris also designed and built the secondary mirror cell assembly, which consists of a stiff steel mounting plate, 72 axial and six tangent actuators (that support and control the shape of the thin mirror under changing conditions), the mirror cell electronics and sensors, a thermal control system, and the mirror control system.

The secondary mirror assembly was installed on the telescope mount in late July 2024.



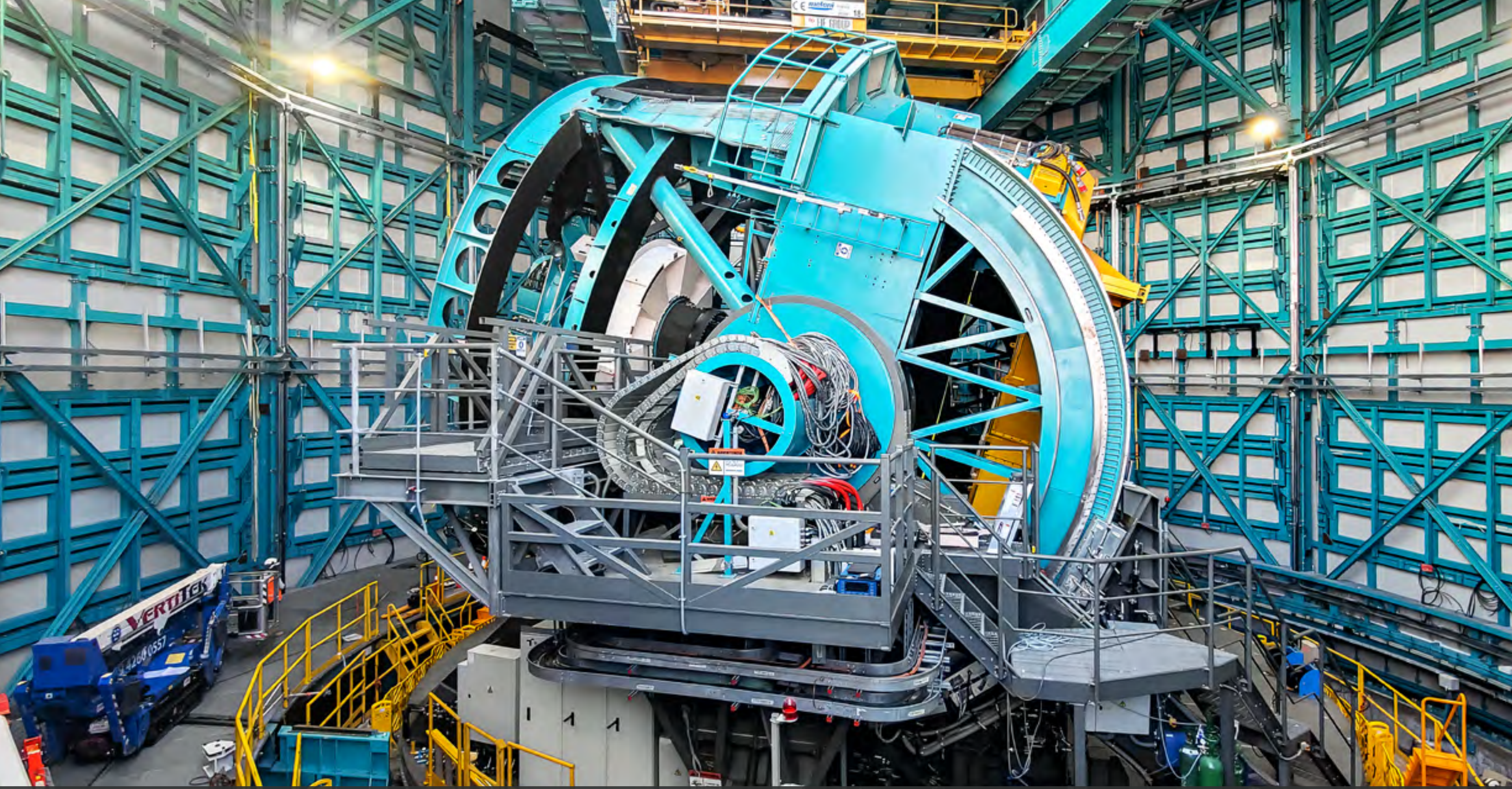
Rubin Observatory's 3.5-meter secondary mirror installed on the Simonyi Survey Telescope (image modified to enhance visibility of mirror). Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/H. Stockebrand

Telescope Mount

The telescope mount is the enormous steel structure that supports Rubin's mirrors and the LSST Camera, as well all the utilities that make the Simonyi Survey Telescope function. Rubin's telescope mount was designed to be rigid yet relatively lightweight. This helps reduce vibration as the telescope darts from one field of view to the next, so the LSST Camera can be ready to take another sharp, clear image after just a few seconds. Rubin is the fastest-slewing large telescope in the world — it only takes about five seconds to move and settle between two nearby areas of sky.

The quick motion presented challenges that required innovative solutions. The telescope is powered by linear motors that limit noise and vibration as the telescope moves from one position to another. A huge bank of capacitors under the telescope boosts the electrical power to the motors. These capacitors were installed before the telescope was assembled above them, and they're designed to last for the whole 10 years of the LSST survey and beyond. When the telescope slows down and stops at a new observing point, the slowing motion sends energy back to the capacitors, helping charge them up again — similar to the concept of regenerative braking in electric vehicles.

The Rubin Observatory telescope mount in October 2024. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA



Rubin Observatory's telescope mount in May 2023. Credit: Rubin Observatory/AURA/DOE/NSF

The optical components of the telescope — the camera, the combined primary/tertiary mirror, and the separate secondary mirror — can all be removed from the telescope mount when necessary for major maintenance or repairs. The mirrors, for example, will need to be stripped and recoated a few times during the 10-year survey. When it's time for this activity, staff will remove the mirrors from the structure and transport them to the maintenance floor of the facility using carts mounted on rails set in the floor, and the observatory's vertical platform lift.

A variety of organizations worked together to design and build this complex structure. The telescope mount was designed by GHESA lngeniera y Tecnologia, S.A. It was constructed at Asturfeito, S.A, in northern Spain. The design of the mount control, camera cable wrap, and mirror covers is by IK4 Tekniker. The design and fabrication of the azimuth and elevation linear drives and capacitor bank are by Phase Motion Control.

The telescope mount was fully assembled and tested on the factory floor in Spain in 2019. Then it was disassembled and shipped to Chile as a 26-piece cargo shipment. The longest piece was 14 m (46 ft) long, and 4.5 m (15 ft) high. Once all the shipping crates arrived in Chile, they were transported to Cerro Pachón and the structure was re-assembled on the telescope pier inside the observatory.

LSST Camera

Credit: SLAC National Accelerator Laboratory

Overview

The LSST Camera is the 3200-megapixel camera mounted on the Simonyi Survey Telescope at NSF–DOE Vera C. Rubin Observatory. It's the largest digital camera in the world — the size of a car and weighing about 2800 kg (6000 lbs). The LSST Camera was built at SLAC National Accelerator Laboratory in California with funding provided by the U.S. Department of Energy, Office of Science. The camera has a field of view so large it could contain 45 full moons — a total of 10 square degrees. The LSST Camera is capable of viewing light from the near-infrared (limited by the camera's sensor sensitivity), through optical wavelengths, and into the ultraviolet (limited by the Earth's atmosphere).

The camera's range of wavelengths is divided into six bands associated with filters (from ultraviolet to near-infrared) labeled *u*, *g*, *r*, *i*, *z*, and *y*. These glass filters are the largest in astronomy — about 30 inches (75 centimeters) in diameter. The color information provided by the filters will help scientists study different physical processes that emit or absorb light at different wavelengths.

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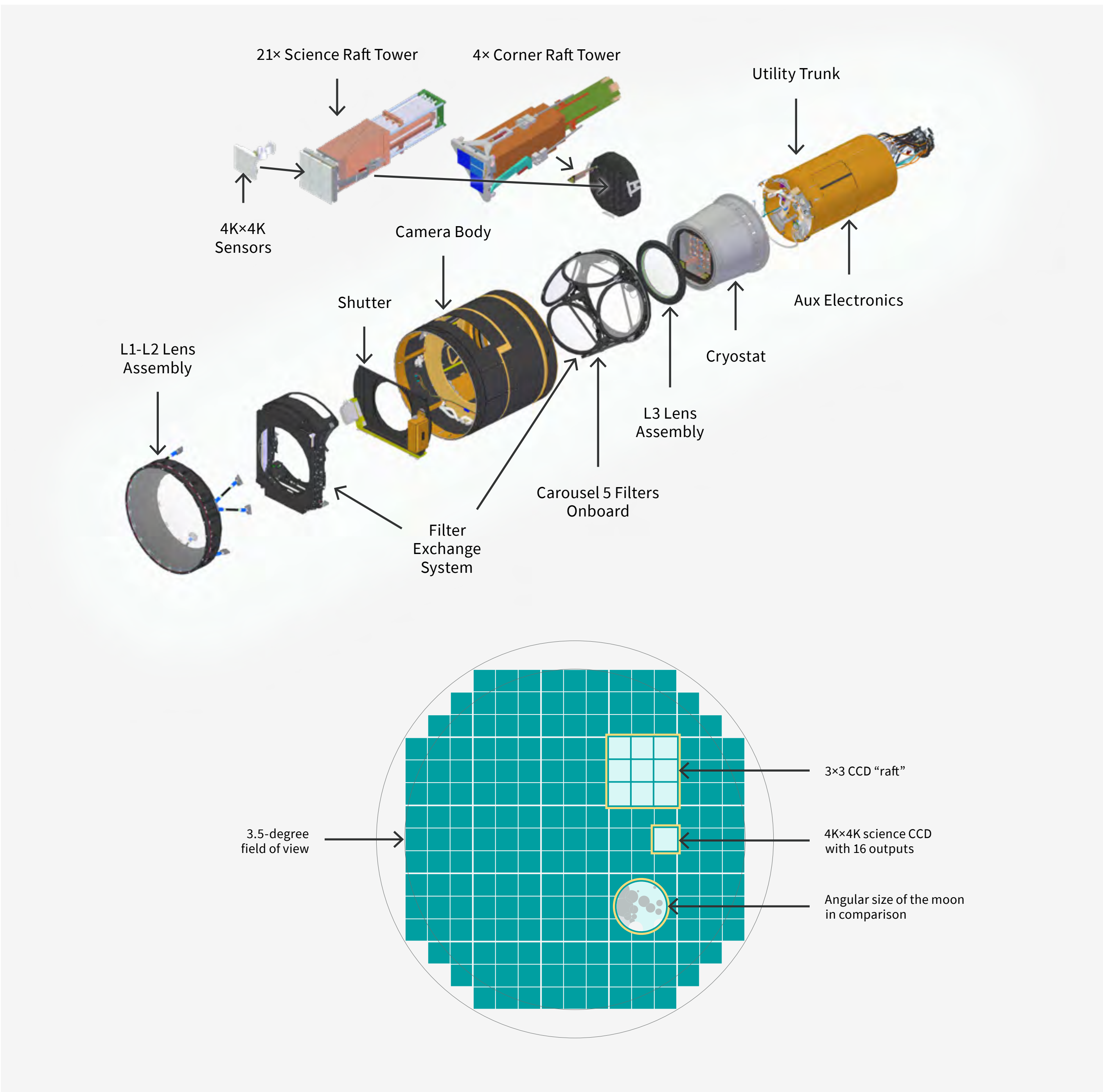
LSST Camera Deputy Project Manager Travis Lange shines a flashlight into the LSST Camera. Credit: J. Ramseyer Orrell/SLAC National Accelerator Laboratory

The LSST Camera has three massive lenses. The biggest lens, at 5.1 feet (1.57 meters) in diameter, is the largest high-performance optical lens in the world. After passing through the lenses, light reaches the camera's focal plane, which is made up of 201 individual custom-designed charge-coupled device (CCD) sensors, and it is so flat that it varies by no more than a tenth the width of a human hair. The pixels themselves are only 10 microns wide.

The camera has a fully integrated cooling system that maintains the temperature of the CCDs at about -100°C, to help reduce unwanted noise in the images. The cooling system is powerful enough to remove 500 watts of heat at -130°C, ensuring the CCDs stay very cold even as they operate.



The camera's most important feature is its resolution, which is so high it would take 400 ultra-high-definition TVs to display just one of its images at full size. The whole telescope is designed in such a way that the imaging sensors will be able to spot objects 100 million times dimmer than those visible to the naked eye — a sensitivity that would let you see a candle from thousands of miles away.

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Among the partner labs that contributed expertise and technology are Brookhaven National Laboratory, which assembled sets of nine CCDs into square units called "rafts," that were then shipped to SLAC and inserted into the focal plane grid (21 rafts make up the 3200-megapixel focal plane); Lawrence Livermore National Laboratory which, with its industrial partners, designed and built lenses for the camera; and the National Institute of Nuclear and Particle Physics at the National Center for Scientific Research (IN2P3/CNRS) in France, which contributed to sensor and electronics design and built the camera's filter exchange system.

The LSST Camera was completed at SLAC in April 2024 and shipped to Chile in May 2024.

Group photo taken on the third level of Rubin Observatory with the LSST Camera, which arrived in Chile on May 16, 2024. Credit: Olivier Bonin/SLAC National Accelerator Laboratory

Lenses

A key feature of the LSST Camera's optical assemblies are its three lenses. The largest of the three measures 1.57 meters (5.1 feet) in diameter and holds the world record for the largest high-performance optical lens.

The smallest of the three lenses is just over 27" in diameter and just under 2.5" thick. This lens serves as the vacuum window to the cryostat where the sensors and readout electronics are housed.

To the left, the photo shows the largest lens of the Vera C. Rubin Observatory camera. Credit: SAFRAN. To the right, the smallest of the three lenses. Credit: Jacqueline Orrell/ SLAC National Accelerator Laboratory

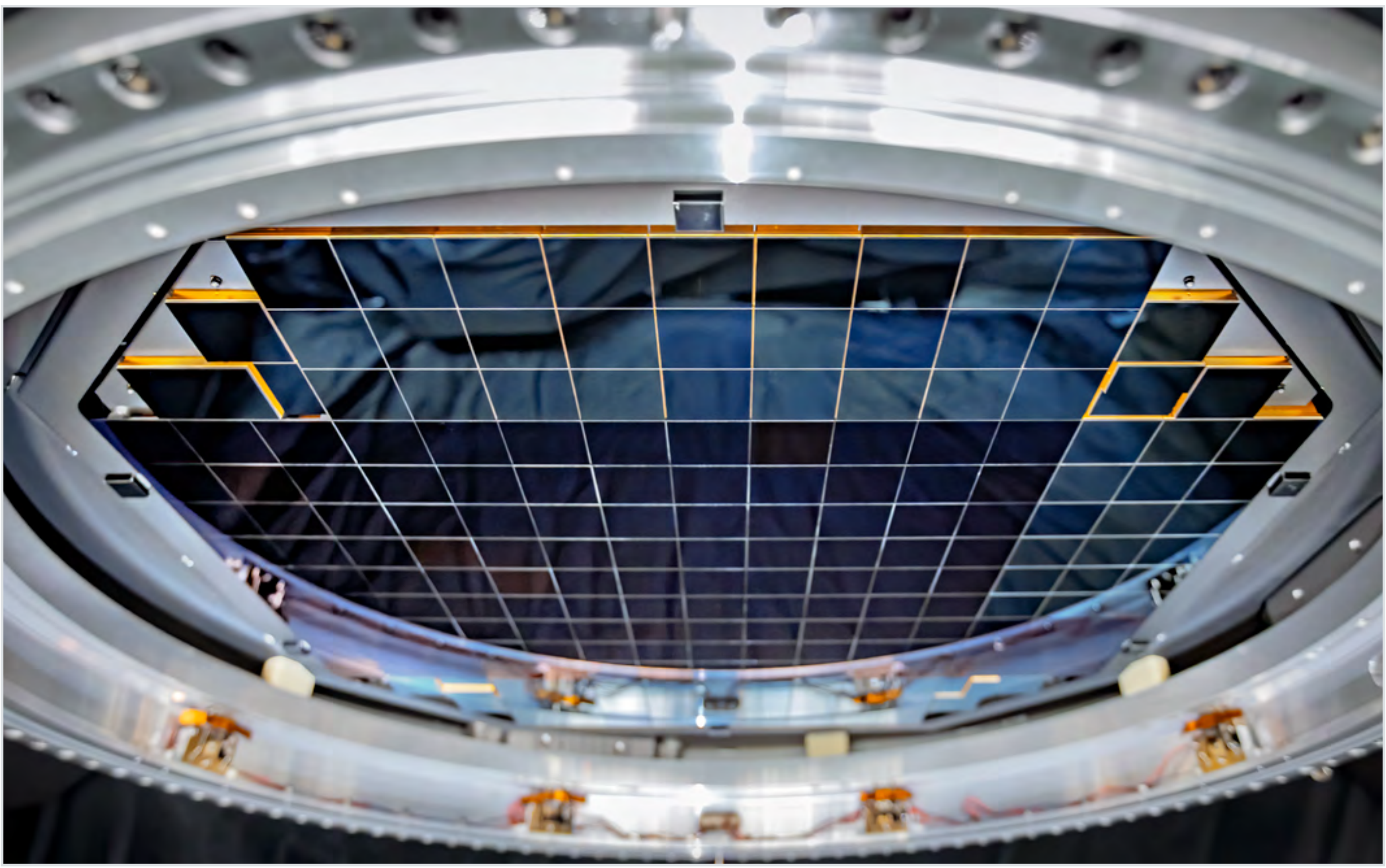
Shutter

The LSST Camera shutter was designed, constructed, and tested at SLAC National Accelerator Laboratory. It takes just 0.9 seconds to either open or close, and it does so with incredible precision. The timing of each open and close is consistent within one thousandth of a second, and it follows the same smooth path every time. This precision as the shutter opens from one side and closes from the other ensures that the focal plane is uniformly illuminated during image capture.

Focal Plane

The focal plane is the heart of the camera, where light from billions of galaxies comes to a focus. It consists of 189 CCD sensors for science imaging, arranged in a total of 21 3x3 square arrays mounted on platforms called rafts, and an additional 12 CCD sensors to provide data for camera and telescope control. Each CCD is 16 megapixels, and there is only a ½ millimeter of space between them.

The 64-cm-wide focal plane corresponds to a 3.5-degree field of view (10 square degrees total area), which means the camera can capture more than 45 times the area of the full moon in the sky with each exposure. Rubin has the shortest time between exposures of any wide-field camera on a large telescope — it takes just two seconds to read the image data from the camera.



The complete focal plane of the LSST Camera is more than 60 cm (2 feet) wide and contains 189 individual sensors that will produce 3200-megapixel images. Credit: SLAC National Accelerator Laboratory

The focal plane electronics were custom-made for the LSST Camera. These sophisticated electronics — which were designed, assembled, and tested at SLAC with key contributions from IN2P3 — read out 48 channels in a single printed circuit board. They are incorporated inside the cooling system vacuum vessel, another technological feat unique to the LSST Camera.

Filters

The optimized wavelength range for the LSST Camera is 320–1050 nm (ultraviolet to near-infrared). This range is divided into six spectral bands, each associated with one of the filters.

The filters themselves are pieces of coated glass housed in a carousel for easy switching during observations — the filter in use sits between the second and third camera lenses. Each filter has a unique coating that lets certain wavelengths of light through while reflecting the rest. Photographers with handheld cameras can easily attach different filters over their lenses manually, but at 75 cm (30 in) across, the LSST Camera filters are too large for that. Instead, a sophisticated machine called the auto-changer changes the camera's filters. At any given time, five of the six filters are mounted in the carousel in the camera so they can be switched in under two minutes while the telescope is operating. The sixth filter is swapped into the camera, replacing another, about once per month.

The six LSST Camera filters in their storage container at SLAC National Accelerator Laboratory, prior to shipping to Chile in May 2024. Credit: SLAC National Accelerator Laboratory

Data Acquisition System

Fiber optic cables at the back of the LSST Camera carry 20 terabytes of data per night down the telescope to a data acquisition system, also custom designed and built by SLAC. This system is robust enough to handle the LSST Camera's 3200-megapixel output datastream in just two seconds. Additionally, it can maintain a buffer of thousands of images gathered over several nights in case the telescope loses contact with the outside world.

Rubin Observatory's data acquisition system moves data from the camera to a computer room on the summit. Credit: RubinObs/NOIRLab/SLAC/DOE/NSF/AURA

Data Management

Taking a new 3200-megapixel image of the southern hemisphere sky about every 40 seconds, NSF–DOE Vera C. Rubin Observatory will produce approximately 20 terabytes of data every night — more data than three years of streaming video, or 50 years of streaming music. By the end of the 10-year Legacy Survey of Space and Time (LSST), Rubin will have collected over 60 petabytes of raw image data — the largest optical astronomical image dataset. Over two million 3200-megapixel images will be collected for the LSST. Managing, storing, and analyzing this massive amount of data requires distributed high-throughput computing, high-bandwidth connections, and significant data storage capacity.

In addition to the raw image data, by the end of the LSST, Rubin's data processing pipelines will produce another 15 petabytes of catalogs containing detailed information about billions of detected objects, such as their positions, brightness, and colors.

The processed data from Rubin Observatory fall into two categories of products: prompt products and annual data releases.

Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Prompt products

Prompt products are real-time processed products that are released within minutes to days of image capture.

Alerts notify scientists of changes detected in the sky. These are generated and released within minutes of image capture.

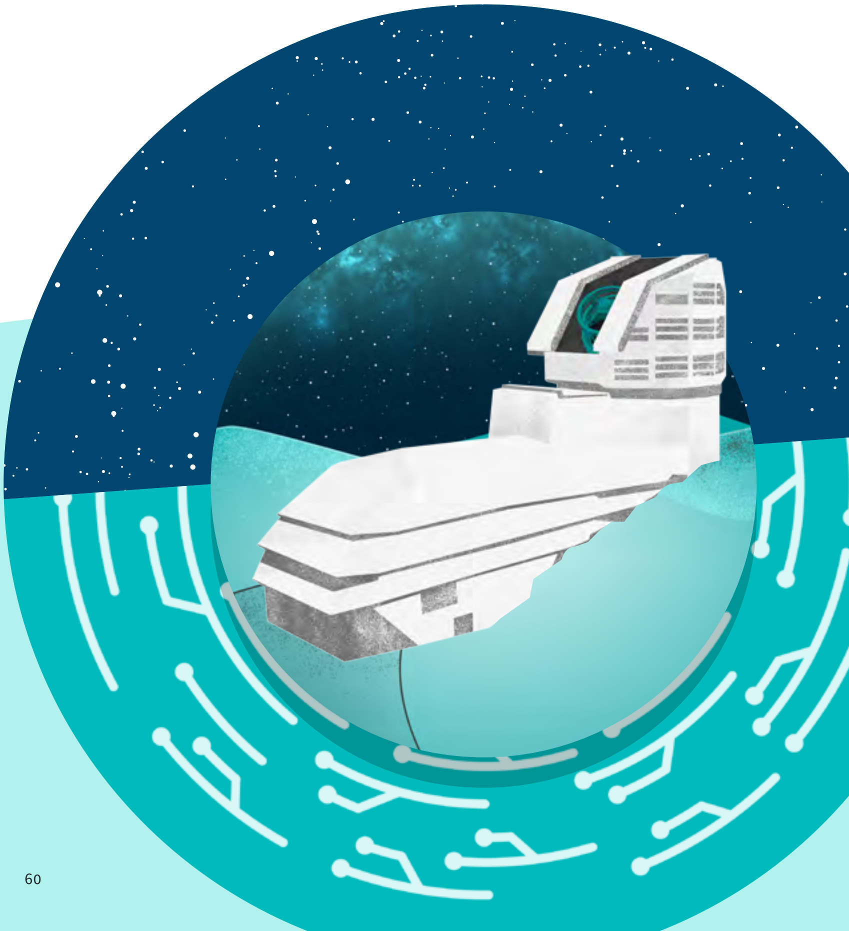
Catalogs contain information about all the objects detected and identified in an image, including transient and variable sources as well as Solar System objects. These are generated within 24 hours.

Raw and processed images, including difference images, are made available to Rubin data-rights holders 80 hours after image capture.

Annual data releases

Annual data releases consist of the calibrated and processed images taken to date. The releases also include catalogs of the billions of detected objects and detailed measurements, such as their positions, shapes, and brightnesses.

The volume and scale of data from Rubin, combined with the scientific requirements for near-real-time processing, make Rubin Observatory's LSST one of the most ambitious data science projects in astronomy and astrophysics to date.



Data Facilities

Rubin's data centers combine to provide petascale computing power. The system that analyzes images to generate the LSST alerts will need to be capable of making about 40 trillion calculations per second.

US Data Facility — SLAC National Laboratory in Menlo Park, CA

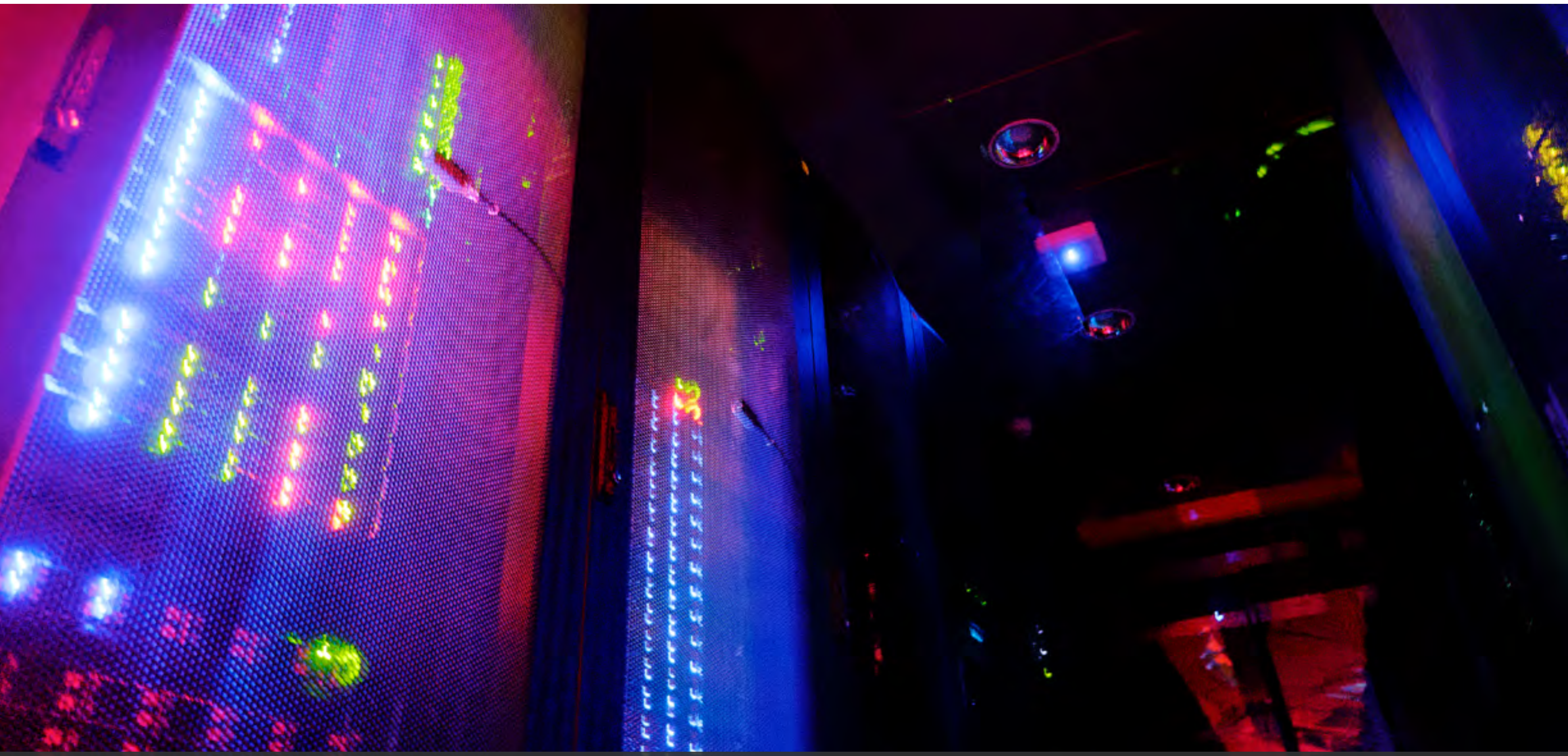
SLAC houses the main data processing, archive, and access center — the front-end of which is hosted on the cloud — for Rubin Observatory. In addition to initial processing and alert generation, SLAC will process about a quarter of Rubin data. SLAC will also ingest and host data processed in France and the UK.

French Data Facility — CC-IN2P3 in Lyon, France

CC-IN2P3, the Computing Center at the French National Institution of Nuclear and Particle Physics, processes 40% of Rubin's data, and also keeps a backup copy of all the raw data.

UK Data Facility, IRIS network, United Kingdom

About a quarter of Rubin's data will be processed by the IRIS network in the UK.



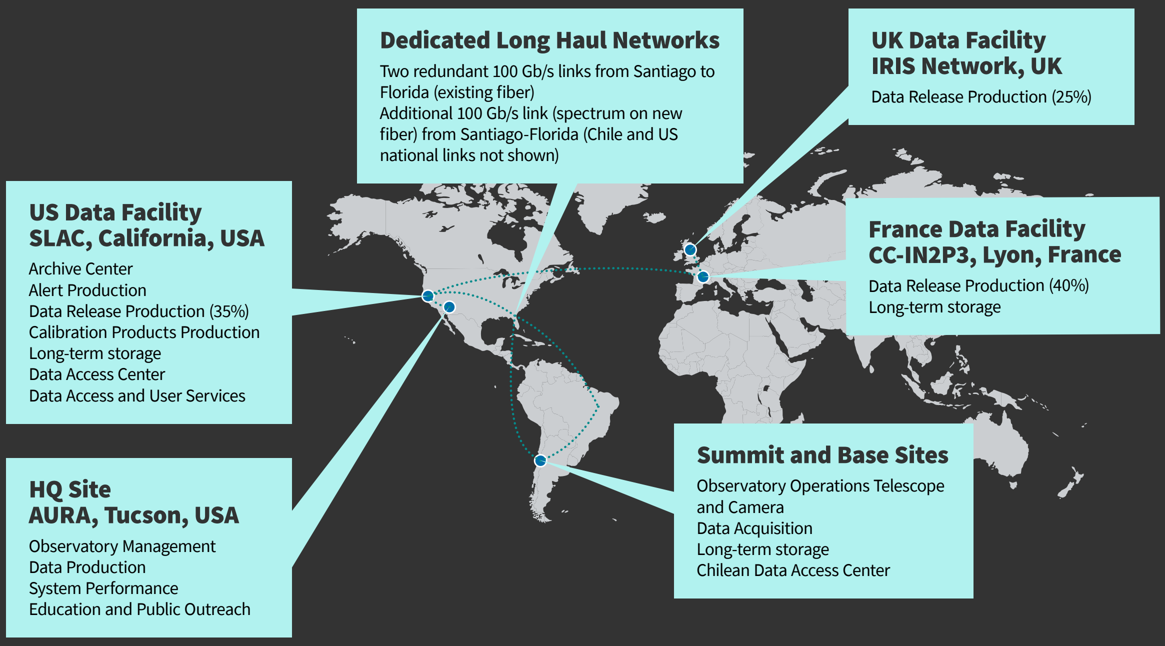
The computer room at Rubin Observatory's summit facility. Credit: RubinObs/NOIRLab/SLAC/DOE/NSF/AURA/W. O'Mullane

Data Transfer

Whenever Rubin Observatory takes an image, the data from that image travel down the mountain to the town of La Serena on high-speed optical fibers that were installed specifically for the task. These fibers have a bandwidth thousands of times larger than the bandwidth of typical home internet. Within a second, the data will arrive at the Rubin base site in La Serena, Chile, before traveling on to Chile's capital, Santiago. From there, the data will travel north through the Pacific Ocean, reaching SLAC National Accelerator Laboratory in California.

The rapid data transfer is enabled by a high-speed long-haul network that connects Chile and California in real time. This network is the result of coordination of Research and Education Networks (RENs) in Latin America with key contributions from Brazil and managed by a consortium led from Florida International University. The network is completed by DOE's ESNET which takes the data arriving from Chile in Atlanta to California and also provides connections to Europe for later processing.

SLAC has the infrastructure to do the prompt, near-real-time nightly processing of Rubin Observatory data. This is done by comparing new images to "template" images. Template images are made by combining previous images of the same region of sky to produce a static view of that area of the sky. By subtracting a template image from a new image, Rubin's data processing software can identify the changes that have occurred from night to night, and even hour to hour. The data processing software, running at SLAC, generates an alert every time a transient, variable, or moving object is detected, resulting in about 10 million alerts every night! The entire process, from image capture to alert, happens within minutes.



Credit: RubinObs/NOIRLab/SLAC/DOE/NSF/AURA

Data Releases

About once a year for the duration of the LSST, Rubin Observatory will release curated catalogs containing billions of objects, with calibrated images and detailed measurements such as positions, shapes, and light emissions. These annual data releases will be accessible to scientists in the U.S., Chile, and supporting institutions around the world, providing them with valuable resources for their research. After the proprietary period of two years, Rubin data will be made available to anyone in the world.

In 10 years Rubin Observatory will detect many more celestial objects than there are living people on Earth: about 20 billion galaxies, and a similar number of stars.

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Data Access

Traditionally, scientists have downloaded astronomical data to do their work. But Rubin produces so much data — trillions of lines of numbers and observations — that it would be nearly impossible for most people to download the whole dataset. Instead, scientists access Rubin data through the Rubin Science Platform. This online portal provides an intuitive user interface, and tools that allow scientists to access and filter the data according to their specific areas of interest.

This distributed and cloud-based way of storing and accessing astronomy data opens the process of science to a much bigger group of people. Traditional methods of doing astronomy, like reserving telescope time or downloading large datasets with powerful computers, excluded people who didn't have easy access to these resources. With Rubin Observatory, all it takes is an internet connection and the desire to do science using some of the most cutting-edge tools available. Rubin Observatory also provides tutorials for scientists new to the Rubin Science Platform and access to a thriving online community of scientists working together to solve problems and get the most out of Rubin data.

Alert Stream

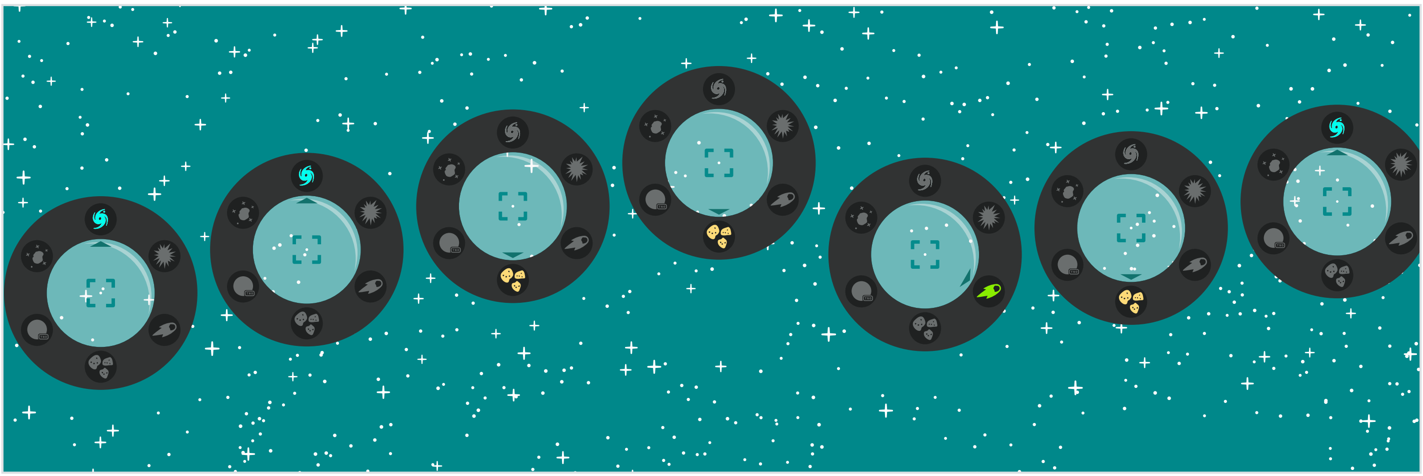
NSF–DOE Vera C. Rubin Observatory will bring the night sky to life, yielding a treasure trove of discoveries: asteroids and comets, pulsating stars, and supernova explosions. Every time Rubin detects a change in an object's position or brightness, it will generate an alert — a total of about 10 million alerts per night.

Rubin excels at detecting changes because it revisits the same area of the sky every few nights, enabling frequent imaging of the same objects. Additionally, its powerful light-collecting capabilities and sensitive camera help Rubin detect even very faint or distant objects.

Credit: NOIRLab/NSF/AURA/P. Marenfeld

Alert Generation

Rubin Observatory's sophisticated software automatically compares each new image with a template built from previous images. The template image is subtracted from the new image, leaving only the changes. Each change triggers an alert within minutes of image capture. Rubin will produce an impressive ~10 million alerts each night, referred to as the "alert stream."



Representation of Rubin's alert stream, which will contain information about every change in the sky Rubin detects. Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/J. Pinto

Managing the Alert Stream

To manage the alert stream, Rubin Observatory alerts will be directed to "community brokers" — software systems that ingest, process, and serve astronomical alerts from Rubin and other surveys to the broader scientific community. The brokers add additional contextual data to each alert. This may include cross-match association with archival catalogs at other wavelengths, light-curve analysis to identify temporal features, and classification into types using machine learning. All of this information allows scientists to identify and prioritize objects for follow-up observations.

Rubin's alerts are world-public; anyone can access them by visiting the website of one of Rubin's alert brokers. Scientists filter these alerts according to their research interest — for example, a scientist studying near-Earth asteroids can use a broker's dashboard tools to identify and focus on alerts related to these asteroids.

Enabling Follow-Up Observations

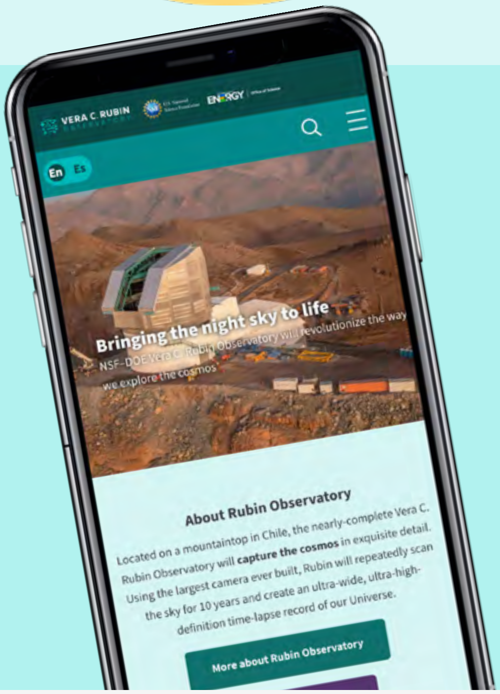
The data provided with each alert can guide crucial follow-up observations. If Rubin detects the brightening of a supernova, which might only be visible for a few days, the alert will provide precise coordinates for other telescopes to observe the event in greater detail, while Rubin continues to search the sky for more changes.

Education and Public Outreach

The NSF–DOE Vera C. Rubin Observatory Education and Public Outreach (EPO) program aims to make Rubin Observatory science accessible, relatable, and engaging for a broad audience. Rubin's EPO program is unique in that it was fully funded by the NSF as a subsystem of the Rubin Observatory construction project, and was developed alongside the physical observatory.

Classroom materials

Rubin's EPO program offers free, online, classroom-ready materials for advanced middle school to college students, requiring only internet access and a modern browser. These materials utilize authentic data without needing special software, focusing on the scientific process and hands-on data manipulation. Rubin also offers professional development and training opportunities — both in-person and online — for teachers who want to engage their students with Rubin data and discoveries.



Public Outreach

Rubin Observatory engages the general public through a mobile-friendly website featuring articles, images, and videos that emphasize accessibility and relevance. Rubin's social media accounts offer timely and engaging content on multiple platforms so people can learn about Rubin where they're already spending time.

Community Participation in Rubin Science on Zooniverse

Anyone can participate in real science with Rubin Observatory data thanks to a partnership between Rubin and the popular community science platform Zooniverse. Rubin and Zooniverse have provided the resources and infrastructure for scientists to easily build projects on Zooniverse, populate them with Rubin data, and invite anyone in the world who wants to contribute to be part of the discovery process. Projects featuring Rubin data will be added to this page on Rubin's website as they come online.

Satellite Constellations

Impact on Rubin Observatory

With the rapid growth of satellites in low Earth orbit (LEO) for telecommunications, the science produced by NSF–DOE Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will face challenges. Companies like SpaceX, Amazon, and others continue to launch thousands of satellites, which can reflect sunlight and interfere with observations. Rubin's wide field of view and sensitive detectors make it especially vulnerable to satellite reflections. Rubin Observatory scientists work with satellite operators, regulators, and international groups like the International Astronomical Union (IAU) to reduce this impact.

Effects on Observations

The increasing number of LEO satellites could leave streaks across the images Rubin Observatory takes each night, making some data unusable and introducing unwanted light that could interfere with findings.

Simulations predict that about 10% of Rubin images will contain at least one satellite trail, with this number rising near sunrise and sunset. Rubin scientists are exploring ways to minimize streaks, including changing where the telescope points or identifying satellite trails in data to avoid sending alerts based on artificial signals. However, Rubin data may still contain some false sources, especially in the twilight hours when satellites are most visible.

Starlink Satellites over Carson National Forest, New Mexico, photographed soon after launch. Credit: M. Lewinsky/Creative Commons Attribution

Global Efforts to Protect the Night Sky

The IAU, NOIRLab and the SKAO have set up the Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS), working with scientists, policymakers, and satellite operators to develop brightness standards and protections for astronomy. The United Nations has also begun discussions on managing the effects of satellite constellations on astronomy, with a focus on preserving the night sky.

Recently, the U.S. National Science Foundation awarded funding to create tools to better track and predict satellite positions and brightness. This will help Rubin adjust its observing schedule to avoid the brightest satellites.

Credit: Rubin Observatory/NSF/AURA/A. Pizarro D.