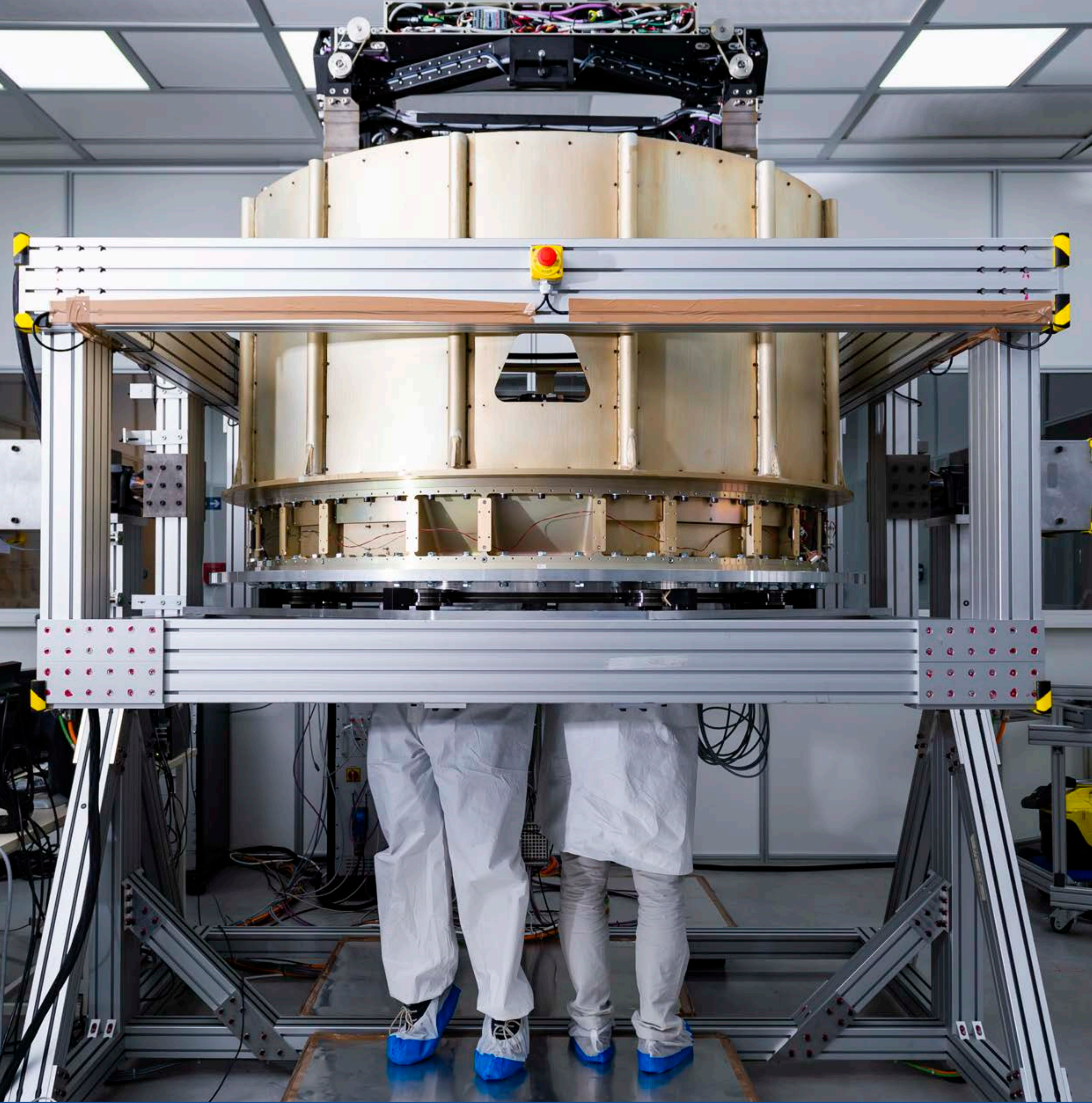

FRANCE IN THE LSST SURVEY

Vera C. Rubin Observatory

National institute of nuclear physics and particle physics


Large Synoptic Survey Telescope
APC

Credit: Patrick Dumas / IN2P3 CNRS

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Credit: Gianluca Lombardi

THE RUBIN OBSERVATORY OPENS A NEW ERA OF TELESCOPES WITH UNPRECEDENTED OBSERVATION CAPABILITIES

From 2022, and for a ten year period, the Vera C. Rubin Observatory will carry out an unprecedented optical survey of the visible sky named the Legacy Survey of Space and Time (LSST).

The LSST survey conducted by the Rubin Observatory should improve our knowledge of the universe by determining the nature of dark energy and dark matter, constituting an inventory of the solar system and a cartography of the Milky Way.

The project is a large international collaboration driven by the United States and in which France plays a fundamental role. Founded in 2003, it involves several hundreds physicists, engineers, and technicians.

The headquarters of the Project Office are located in Tucson, Arizona. In the United States, the project has been thought as a multi-agencies public-private partnership. The National Science Foundation, which leads the project, is in charge of funding the telescope, site, and data management. The Department of Energy builds the camera and manages the participation of the particle physics community. Private funds have been raised to start the production of the mirrors and fund research and development activities on the CCD sensors. Entrepreneurs Bill Gates and Charles Simonyi have, for instance, invested 30 million dollars in the project.

Besides the US, only two countries, out of the dozen contributing to the Rubin Observatory, are involved in its construction: **France, through several laboratories of the National Institute of Nuclear and Particle Physics (IN2P3) from CNRS**, and Chile which will host the telescope.

More than 900 researchers all around the world will analyze the data produced by the Rubin Observatory.

A ONE-OF-A-KIND INSTRUMENT

THE RUBIN OBSERVATORY IS A ONE-OF-A-KIND INSTRUMENT WHOSE CHARACTERISTICS ARE SUMMARIZED BELOW.

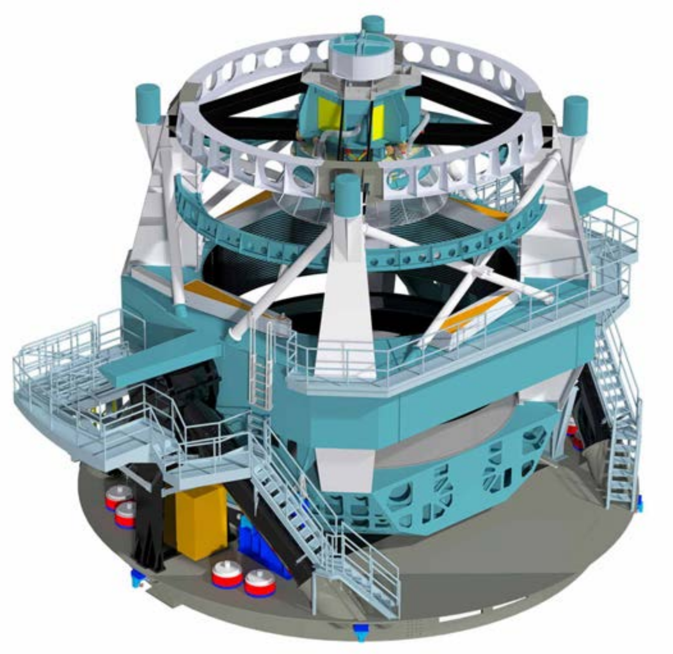
The Legacy Survey of Space and Time will be conducted at the Vera Rubin Observatory thanks to three essential parts: the Simonyi Survey telescope, the LSST camera, a uniquely designed camera for the survey, and the data management system.

The region of Cerro Pachón has been selected to host the Rubin Observatory for its preserved and favorable to astronomical observations environment. The high altitude limits the air mass and the site is renowned for its clear nights and low hygrometry.

With a diameter of 8.4 meters, the Simonyi Survey telescope relies on a Paul-Baker design with three mirrors to obtain a very wide field of view (9.6 square degrees), which corresponds to 40 full moons.

Thanks to a very compact optic, the telescope will be able to detect very faint objects with a very short exposure time. Light will be reflected by 3 mirrors and 3 optical lenses. The Simonyi Survey telescope will then be able to scan half of the sky in only three nights.

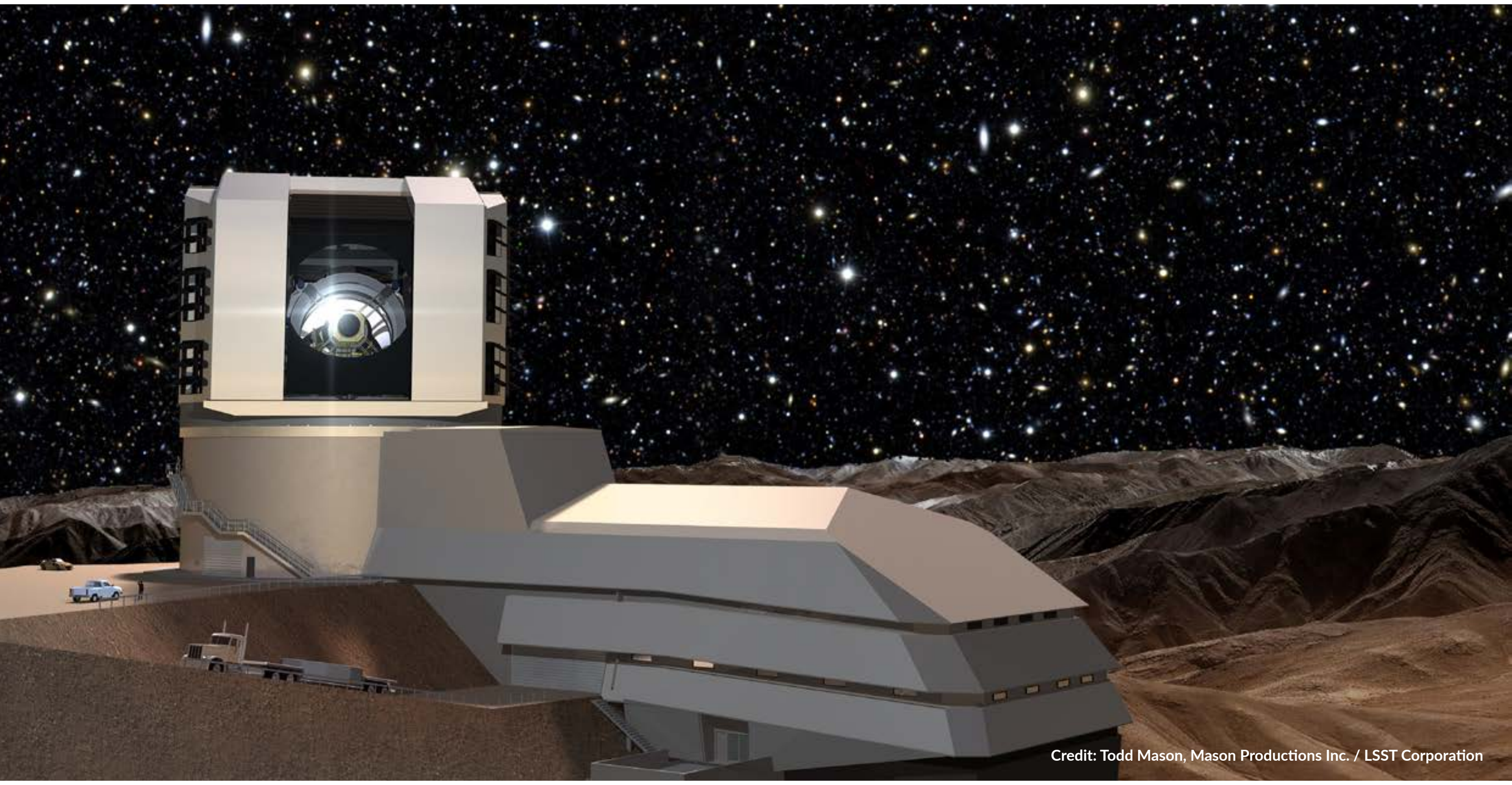
Moreover, the Rubin Observatory will be equipped with light baffles, wind protection, and thermal controls with natural ventilation to protect it from temperature variations during daytime.



Credit: LSST Project/NSF/AURA

SCIENTIFIC GOALS

THE OBJECTIVE OF THE LEGACY SURVEY OF SPACE AND TIME IS TO ALLOW SCIENTISTS TO ANSWER THE STILL PENDING KEY QUESTIONS ON THE STRUCTURE AND EVOLUTION OF THE UNIVERSE.



Credit: Todd Mason, Mason Productions Inc. / LSST Corporation

The Nature of Dark Matter and Understanding Dark Energy

LSST will probe the nature of dark matter and dark energy using several billion galaxies, employing a variety of methods to enable cross-checking of results.

Cataloging the Solar System

LSST will undertake a thorough exploration of our Solar System with two goals in mind: learning how it originally formed, and protecting Earth from hazardous, near-flying asteroids.

Exploring the Changing Sky

By imaging the entire night sky repeatedly, to great depth, and with excellent image quality, LSST will reveal new information about known kinds of variable stars and cosmic explosions, as well as discover entirely new classes of transient events.

Milky Way Structure & Formation

The LSST observations will yield the motions of millions of Milky Way stars. When stacked in depth, this set of observations will yield a map over 1,000 times the volume of past surveys, cataloging the colors and brightnesses of billions of new stars.

LSST SCIENCE AT CNRS-IN2P3

LSST will unveil one of the greatest mysteries of our time: the nature of the mysterious dark energy which is expanding our Universe at an increasing rate, a discovery that has been awarded the 2011 Nobel Prize.

This scientific question is at the heart of IN2P3's cosmology program, and builds on the pioneering work of the institute's teams on type Ia supernovae and baryon acoustic oscillations.

But dark energy also acts, along with dark matter, on the formation of the large structures of the Universe, and, in parallel with the observation of supernovae, a second field of investigation is now opening up to IN2P3 teams.

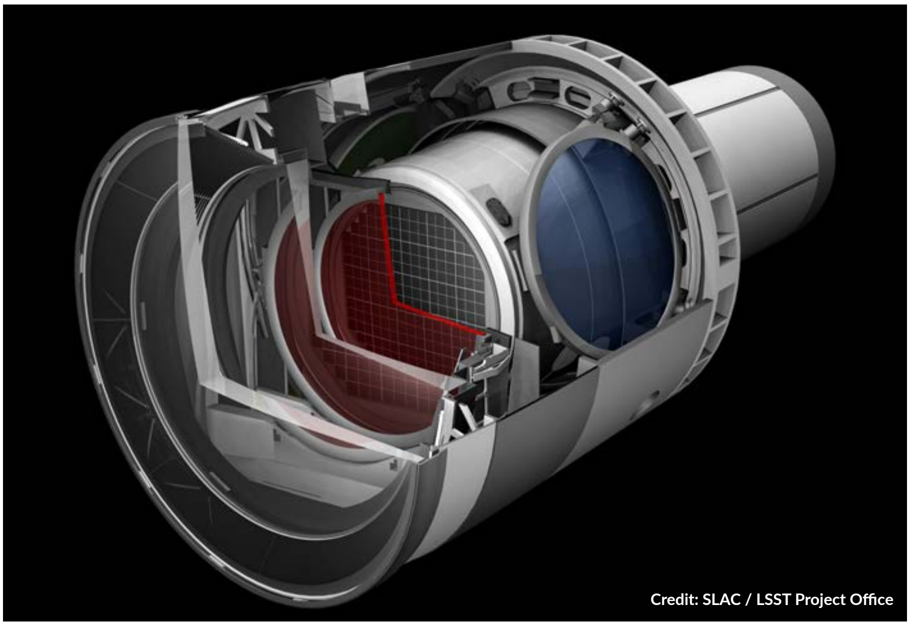
In combination with the light from the farther universe, this will provide a complete cosmological picture, thanks to the unprecedented depth and sky coverage of the LSST.

LSST DESC is the international science collaboration that will make high accuracy measurements of fundamental cosmological parameters using LSST data. **IN2P3 plays an active role in this collaboration with 33 IN2P3 full members, 15% of the total.**

THE LARGEST DIGITAL CAMERA

The LSST camera is the largest digital camera ever constructed. It's roughly the size of a small car and weighs almost 2.8 tons. It is a wide-field optical imager capable of viewing light from the near ultraviolet to near infrared. The camera focal plane is composed of a mosaic of 189 CCD science imaging devices and 12 CCD technical imaging devices, for a total of 3216 video-channels. With 3.2 billions pixels, it will produce data of extremely high quality at a high rate with minimal downtime and maintenance allowing physicists to measure precisely the faintest objects. The SLAC National Accelerator Laboratory (California, United States) is leading the construction of the camera.

CNRS-IN2P3, France, plays a key role in the construction of the camera by contributing to the focal plane effort and by providing several essential parts such as the Filter Exchange System and the Camera Calibration Optical Bench (CCOB).



Credit: SLAC / LSST Project Office

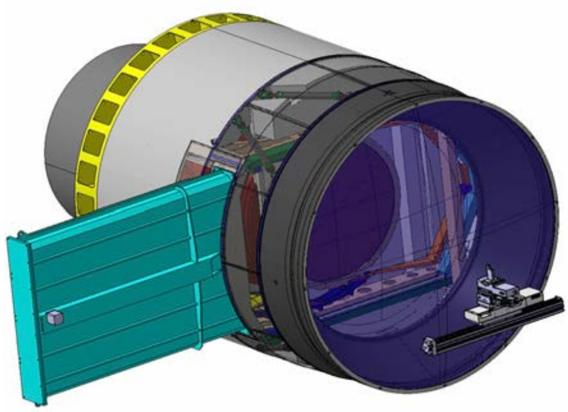
LSST CAMERA FOCAL PLANE AT CNRS-IN2P3

IN2P3 teams contribute to the design, construction, and optimization of the unique LSST camera focal plane. A team from IJCLab, Orsay, and LPNHE, Paris, laboratories developed an Application Specific Integrated Circuit (ASIC) for the highly compact CCD readout electronic. It is designed to pre-process the CCD signal at the entry of the video-channel. Following this early contribution, the LPNHE team contributes to the optimization of the operation and readout of the focal plane CCD and is in charge of the FPGA micro-code that drives the focal plane sensors. As part of this effort a laboratory dedicated to CCD has been build for the LSST camera at LPNHE and is used by the project to address key issues for the camera on its CCD, electronic readout, or performance optimization.

Credit: Patrick Dumas / IN2P3 CNRS

CHARACTERIZATION AND CALIBRATION

The success of the science enabled by the LSST will strongly depend on its camera response understanding. IN2P3 scientists and engineers are working on various topics to get this knowledge. The LMA-IP2I laboratory in Lyon made an early contribution to the design of the LSST camera filters. The LPSC laboratory in Grenoble delivered a system, the CCOB, to allow a characterization of the camera prior to its installation in Chile. More generally efforts involving IN2P3 teams are underway in various astronomical sites to prepare the survey calibration of the Rubin Observatory.



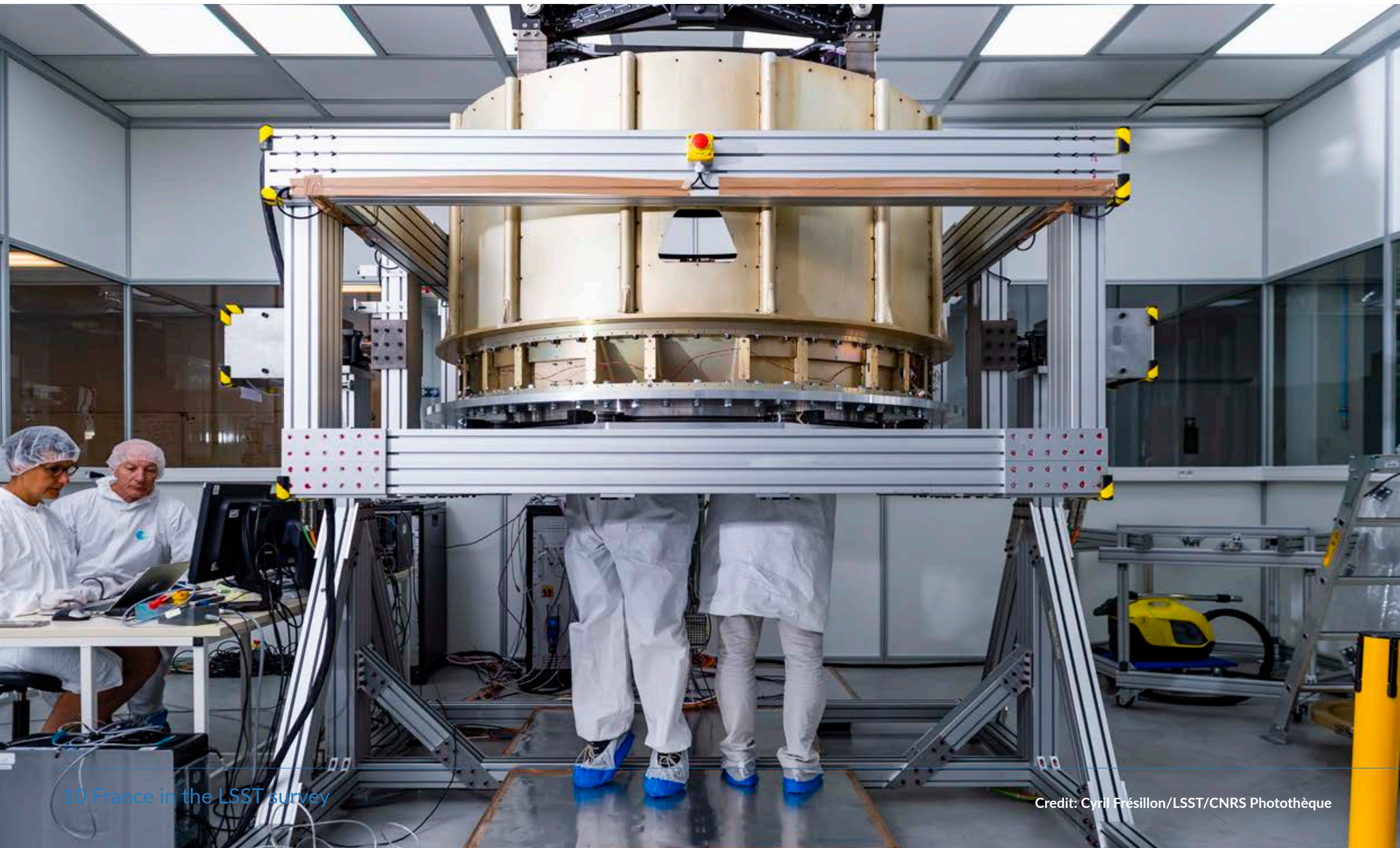
The camera subsystems are monitored and controlled by the **Camera Control System (CCS)**, which was originally designed at the APC laboratory, in Paris, and whose core features are jointly developed by APC and the SLAC National Accelerator Laboratory.

FILTER EXCHANGE SYSTEM

A FRENCH COLLABORATION

To measure the distance of galaxies, we analyze the spectrum/color of the light they emit. On the Simonyi Survey Telescope, these measures will be done based on the information provided by six filters installed on the LSST camera. The filters with their frame weigh between 25 and 38 kg, and have a diameter of ~70cm. In a given night five of these filters will be present in the camera and the filter exchange system will allow to use any of them to observe the sky for a fraction of the night, keeping the four others out of the telescope beam.

The filter exchange filter is a robotic system made of three subsystems built by several CNRS-IN2P3 labs and controlled by a control/command system developed by the APC laboratory. It was assembled at LPNHE in Paris, and then shipped to the SLAC National Accelerator Laboratory (California, United States) at the end of 2019.



Credit: Cyril Frésillon/LSST/CNRS Photothèque

The **carousel** is designed to store up to five filters and to position the right filter in front of the autochanger in less than 15 seconds. Its locking system allows to keep the filters at their location with full safety. It has been built at LPNHE, in Paris.

The **autochanger** is designed to grab a filter from the carousel and place it in front of the camera focal plane with a granted accuracy of 0.1 mm. This component has been developed in Marseille (in the south of France) by a team of the CPPM.

The LPSC in Grenoble built the **loader** a small clean room (iso6) that can be connected to the camera. The loader allows the initial loading in the camera of five filters then the exchange, during day time, of any installed filter by another one located in a storage area.

A **mechanical test bench** has been deployed by the LPC Clermont in order to qualify the various components of the filter exchange system prior to their integration in the camera. Its support allows to scan every angular position of the telescope and to simulate the rotations of the LSST camera.

VRO leveraged the expertise of the IP2I laboratory (in Lyon), through the LMA technical platform, to propose **a characterization of the anti-reflective treatments** of the camera lenses and the u-g-r-i-z band filters.

DATA PROCESSING

Credit: Cyril Frésillon/CCIN2P3/CNRS Photothèque

More than 20 Terabytes[1] of data produced nightly by LSST will be stored and processed. This will lead to the world largest non-proprietary astronomical catalog at the end of the 10 year-long survey.

The compact design and the enormous light collection capacity will allow the telescope to rapidly scan the sky for fleeting, rare astronomical events. It will detect and catalog billions of objects in our universe, monitoring them over time, and will provide this data – more than 20 terabytes each night – to astronomers, astrophysicists and the interested public around the world.

An integral copy of LSST data will be stored at the IN2P3 Computing Center (CC-IN2P3 / CNRS), in Lyon (France), which will contribute processing half of the data jointly with the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (USA), which hosts another integral copy.

By 2022, CC-IN2P3 will devote to LSST a storage capacity of more than 50 PB and a computing platform composed of about 20,000 CPU cores to process the data coming out of the telescope. This capacity will increase to more than 140,000 cores and 350 PB of storage by the end of the project 10 years later.

To enable a prompt, continuous, and fast transfer of such a large amount of data, dedicated network bandwidth between NCSA and CC-IN2P3 is being deployed, with the support of RENATER, the French National Research and Education Network provider, and GEANT for the transatlantic link.

LSST data access centers will provide researchers with a set of services to query the astronomical catalog database and to perform scientific analysis of the data. They will be hosted at NCSA and in La Serena, Chile. CNRS-IN2P3 will provide its scientists with the computing infrastructure for the scientific exploitation of the LSST data.

The specific role of IN2P3 in the project guarantees an immediate access to LSST data to its researchers, without waiting for the two years delay before data are publicly released. This access will allow IN2P3 scientists to perform their research in the best possible conditions.

1. A Terabyte (TB) corresponds to 10^{12} bytes

STATS

FUN FACTS & KEY NUMBERS

1

pixel of the camera covers the surface of a soccer field on the moon

3.2

gigapixel camera, equivalent to 201 camera of 16 megapixels each

8.4

the size of the biggest mirror of the telescope, the width of a tennis court

10

years to scan the sky

20

Terabytes of data to analyze every night

37

billion stars and galaxies observed

40

Each image has the size of 40 full moons

670

millions dollars for the building cost

Millions

of alerts on transient objects (asteroids, supernovae, ..) every night

CNRS-IN2P3 LABS INVOLVED IN LSST

IN2P3 PI: EMMANUEL GANGLER (LPC)

Name	City	Director	Affiliation
IN2P3 Computing Center	Villeurbanne	Pierre-Etienne Macchi	CNRS
Astroparticule et Cosmologie	Paris	Antoine Kouchner	CNRS/CEA/ Université Paris Diderot/Observatoire de Paris
Centre de Physique des Particules de Marseille	Marseille	Cristinel Diaconu	CNRS/Aix Marseille Université
Laboratoire de Physique des 2 Infinis Irène Joliot-Curie	Orsay	Achille Stocchi	CNRS/ Université Paris-Saclay / Université de Paris
Laboratoire des Matériaux Avancés - Institut de Physique des 2 infinis de Lyon	Villeurbanne	Laurent Pinard	CNRS / Université Lyon 1 / Université de Lyon
Laboratoire d'Annecy de Physique des Particules	Annecy	Giovanni Lamanna	CNRS / Université Savoie Mont Blanc
Laboratoire de Physique de Clermont	Clermont-Ferrand	Dominique Pallin	CNRS/Université Clermont Auvergne
Laboratoire de Physique Nucléaire et de Hautes Energies	Paris	Marco Zito	CNRS / Sorbonne Université / Université de Paris
Laboratoire de Physique Subatomique et de Cosmologie	Grenoble	Arnaud Lucotte	CNRS/Université Grenoble Alpes
Laboratoire Univers et Particules de Montpellier	Montpellier	Denis Puy	CNRS / Université de Montpellier

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