BBC

THE LATEST KIT FOR SOLAR OBSERVING

THE UK'S BIGGEST SELLING ASTRONOMY MAGAZINE

Sky at Night

JUNO REACHES JUPITER

How long can the orbiter survive the giant planet's harsh radiation?

STAR TRAIL SECRETS

Take your best photos of the night sky's motion

BONUS WEB CONTENT

MISSION TO MOVE AN ASTEROID

We speak to the head of the Asteroid Impact Mission to strike a space rock

- VIRTUAL PLANETARIUM
- SKY AT NIGHT EPISODE
- OBSERVING GUIDES
- AND MUCH MORE...

FAREWELL TO CERES

Dawn mission ends study of the icy dwarf planet

DIGITISING THE SKY

How the LSST observatory will supercharge astronomy

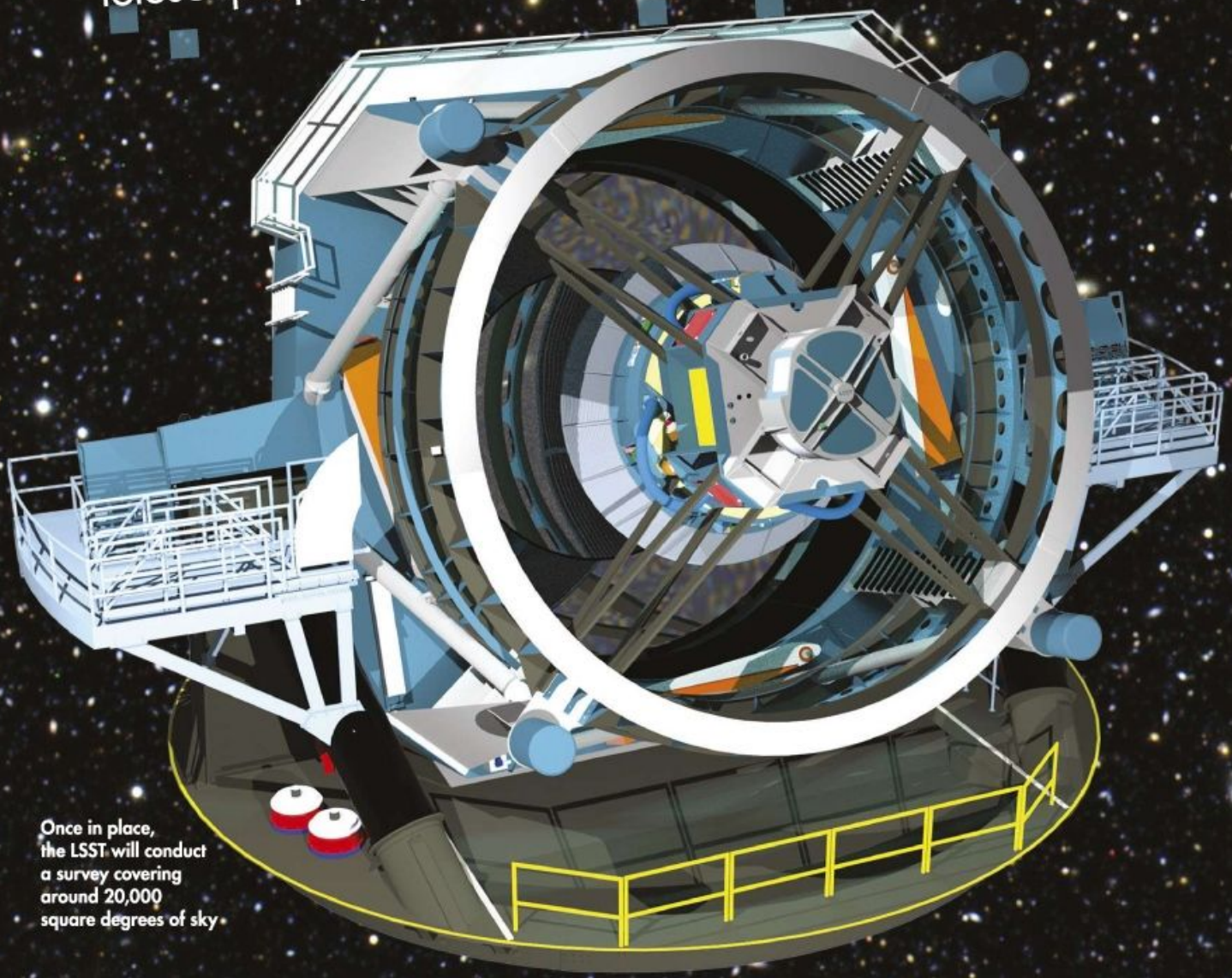
PLANETARY FORECAST

The wildest weather in the Solar System

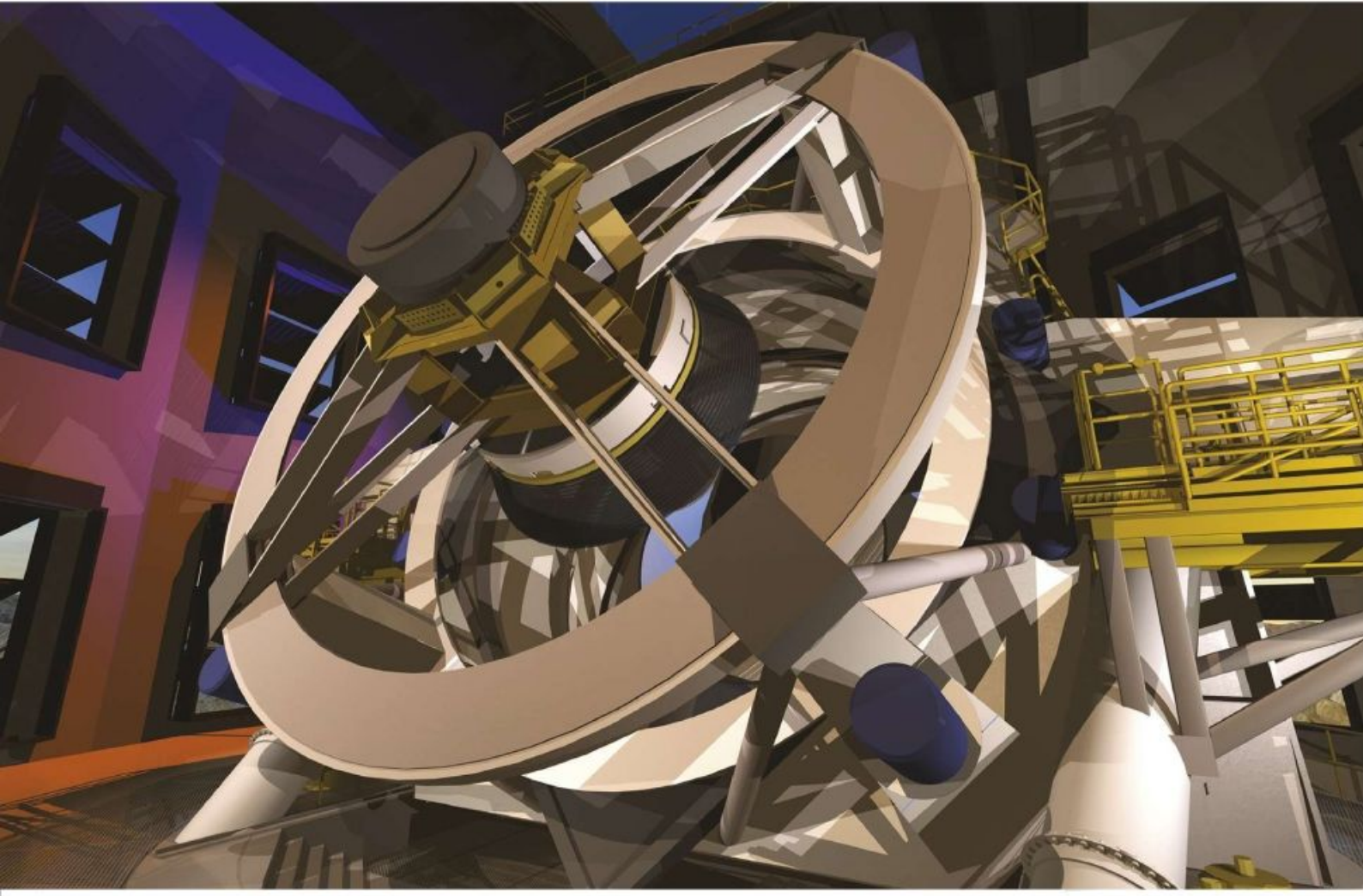
JULY 2016
#134
www.skyatnightmagazine.com

Digitising the sky

The Large Synoptic Survey Telescope, under construction in northern Chile, has been described as the most important telescope project on Earth. **Eagle Gamma** finds out why



Once in place, the LSST will conduct a survey covering around 20,000 square degrees of sky



▲ An artist's impression of the completed telescope

The Large Synoptic Survey Telescope (LSST) will conduct a decade-long digital survey so big that it will change the way researchers do astrophysics and reorientate amateur astronomy. The massive sky survey marks the era of the virtual observatory, and the three-dimensional video of the Universe it will produce could pave the way to primarily digital observations of the cosmos, doing away with the need for observational astronomy.

The LSST team calls this approach the 'New Sky', and claim that the project will observe more in its first month than all previous telescopes ever have, put together. With the world's largest digital camera and biggest data collection capacity, the scope will enable all kinds of research; the agenda covers everything from near-Earth asteroids to distant stars, from galaxies to cosmology.

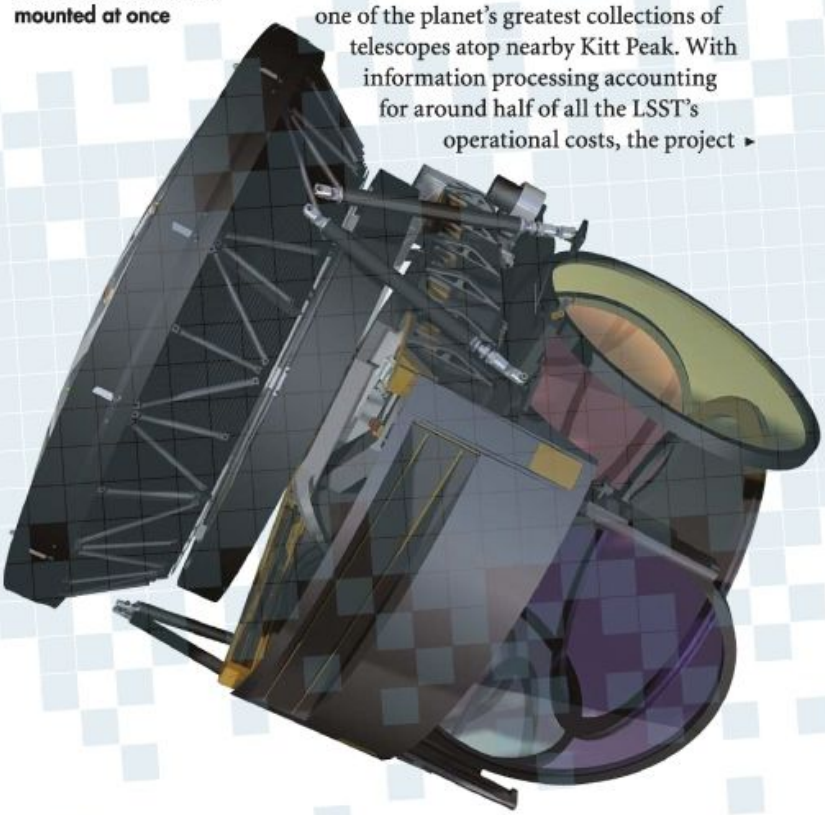
"In a nutshell, LSST is a deep survey of the southern sky, covering about 20,000 square degrees," says LSST systems scientist Chuck Claver. "We'll do it with six spectral filters that cover the optical spectrum."

The database created from this survey will provide a library of 20 billion celestial objects. Astronomers will constantly analyse incoming data, looking for transient events – objects that change over time. Simply to convert the raw data from the hardware into useful imagery will be a huge hurdle. Hundreds of teraflops of computational power will need to kick into high gear, with around a gigabyte of data being collected per galaxy, the billion-dollar telescope will observe many billion stars and galaxies in its lifetime. Imagine the citizen science project this could lead to: every person on Earth could have their own galaxy to explore.

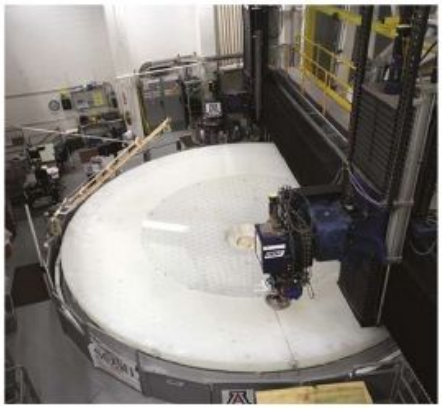
Most important project

The development of the LSST is being organised by the National Optical Astronomy Observatory (NOAO) at its headquarters in Tucson, Arizona. It conducts research with one of the planet's greatest collections of telescopes atop nearby Kitt Peak. With information processing accounting for around half of all the LSST's operational costs, the project ▸

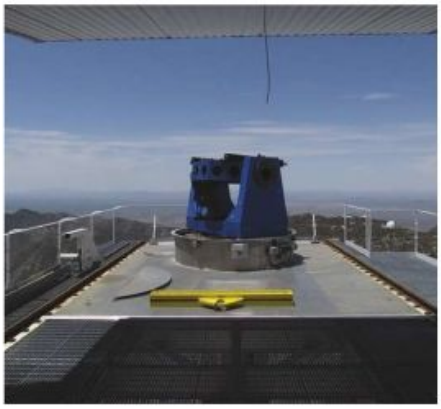
▼ Five of the scope's six coloured filters can be mounted at once



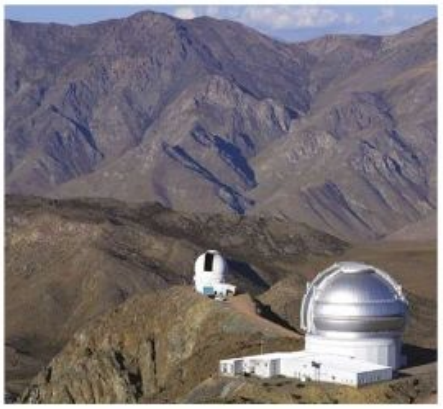
LSST X 4, ISTOCK



▲ Mirror surfaces for the telescope being polished and tested in 2013



▲ Calypso, a small (1.2m) atmospheric telescope that will sit alongside the LSST



▲ The Cerro Pachón location is already home to some traditional telescopes

► also includes facilities at the National Center for Supercomputing Applications in Illinois.

In the major decadal review, *New Worlds, New Horizons*, published in 2010, astronomers determined the LSST to be the single most important telescope project on Earth. In addition to the US Government, financial support comes from some less common sources. Software billionaires Charles Simonyi, Bill Gates and Eric Schmidt have donated tens of millions of dollars.

The facility is expected to be the first telescope capable of detecting most of the asteroids that threaten Earth – up to 90 per cent of them, pushing the detection threshold down from 1km to 140m. Exotic surprises, such as neutron stars or gamma-ray bursts, pop up a lot more often when you can cover more of the sky. We may even discover new types of celestial object altogether.

The device will look at the mysterious increasing expansion of the Universe, to reveal whether it happens uniformly in all directions. Many

LSST X 6, ISTOCK X 3

A GROUNDBREAKING TELESCOPE

At the heart of the LSST are three technologies: the camera, the mirrors and the IT system

SUPER CAMERA

With a resolution of 3.2 billion pixels, equivalent to a thousand smartphones, the LSST's digital camera will be the world's largest, with a mosaic of 189 individual 16 megapixel detectors. The images it captures will have a diameter of 64cm. The physical dimensions of the device are huge: at 3x1.7m and weighing 2,800kg, the camera will be the size of a rhinoceros.

SUPER MIRROR

The f/1 telescope uses a unique composite mirror whose compact design will ease surveys. The 8.4m combination has a field of view of 10 square degrees, and will take in large chunks of sky in a thousand nightly pairs of 15-second exposures. Accumulating tens of thousands of square degrees each week, then rescanning, the telescope will cover over half of the southern sky.

SUPERCOMPUTER

The scale of data-processing needed for LSST data is unprecedented. This is largely an IT telescope, and it will be the largest data system on the planet. Every night, the telescope will generate 30 terabytes of raw data. Over a year, this totals a petabyte (one million gigabytes). After processing, the size will add up to half an exabyte– that's around a quadrillion bytes.

astrophysicists now explain this phenomenon with elusive dark energy. The survey will restrict what this can be, if it even exists; and it may instead uncover new astrophysics.

Construction has started at a dark-sky site on Cerro Pachón in northern Chile, with first engineering light in 2019 and first science light in 2021. The LSST design looks futuristic – a sleek and modern facility. And, through partners including Google, the astronomical flows of data will go around the world.

The telescope uses a unique triplicate mirror, combining primary and tertiary reflectors with a mediating secondary. The combination of mirrors has already been built in Tucson. The entire mirror was first shaped for the primary, then had the tertiary portion ground out of the middle. Sharing the same substrate, both mirrors focus together on a single field.

The composite mirror comes from the famous Steward Observatory Mirror Lab. Here, molten glass gets spun into complex forms, with a honeycomb backing that provides lightness and cooling. The pure borosilicate glass is spun at around 5RPM, then cooled from around 1,150°C over a few months to solidify.

According to Dennis Zaritsky, deputy director of the Steward Observatory Mirror Lab, the mirror shares its genealogy with other top telescopes, including the Large Binocular Telescope and the Giant Magellan Telescope. "All of our mirrors are built to give you images as good as the atmosphere will allow you to get," he says. The triplicate mirrors are a key enabler for this massive survey. "To get the big field of view the design is very different from any other telescope."

A scope like no other

The immense volume of data being collected from the LSST will change the investigative enterprise of astronomy from one of managing optics to one of analysing data. After the LSST's huge survey, it will be easier to study stars online in a virtual observatory instead of through physical instrumentation.

Figuring out the optimal space and time sampling of the sky poses a major challenge, though. "That is the fundamental currency of the LSST," says Victor Krabbendam, the telescope's project manager.

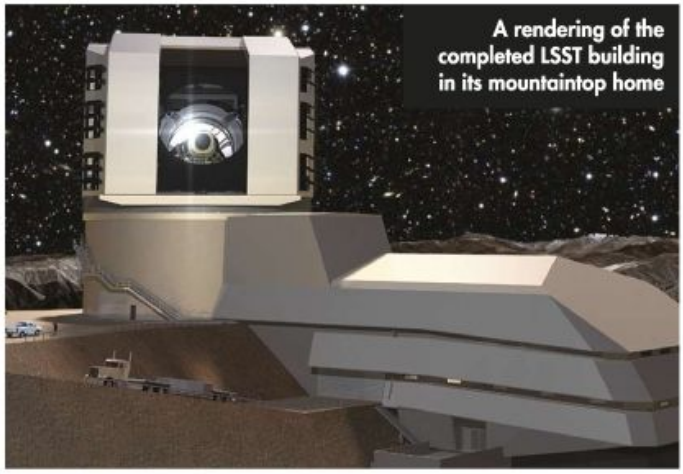
With an average view out to magnitude +24.0, the telescope can focus all the way out to mag. +28.0 – a hundred million times fainter than the human eye can see. This takes the view back to redshift three, to a time when the Universe was around 15 per cent of its present age. "It's deeper, it's wider, and it's faster," says Krabbendam.

Over 5,000 professional astrophysicists will produce research on the basis of the LSST's data set. Citizen scientists will also perform essential investigations, and in doing so the telescope will make the dream of an interactive software version of the Universe into a reality.

And, in recording the evolution of the Universe over a decade, the LSST will make the biggest home movie of all. "The systematic exploration of the time domain across such a large part of the sky has never been done before," says Claver. Zaritsky is equally optimistic: "Every field of astronomy will be advanced," he says. "I think the real revolution in this is the transient Universe."

To get a feel for what the telescope will see, first imagine taking a photo of the Moon. Then, expand the view to a grid the size of seven Moons by seven Moons. Put on 3D goggles, and imagine that you can see thousands of times better than high-definition cameras. Then, watch the sky like this for 10 years.

The LSST is uniting the best of current technology to create a three-dimensional movie of the Universe for everyone to investigate. With it, a digital astronomy revolution is underway.



A rendering of the completed LSST building in its mountaintop home

LARGE SCALE CITIZEN SCIENCE

It's not just professional astronomy the LSST will affect: everyone will have access to the data

LSST data is going to be shared publicly. Alerts from the entire database will become available almost instantaneously, and annual reports will include its entire catalogue. To start, only formal partners will receive the full raw data, in addition to the public processed data. However, a primary goal of the project is to make the overall results available to everyone, notably in the form of an interactive video of the Universe. Improvements to space models like Google Sky and Microsoft's WorldWide Telescope, along with data in simpler formats, will share the astronomy with everyone. The new survey hardware and software promise to kickstart a new age of the fully fledged citizen astronomy.

Take one example: astrophysicists currently know of about 500 gravitational lenses. With the immense repository of LSST data, tens or hundreds of thousands more could be discovered. It will take the time and acuity of citizen scientists to identify them, however: the telescope will produce far too much data for any one observer to deal with.

Going several orders of magnitude deeper than existing surveys, the higher level of information will serve the public a look into our place in the cosmos. The public education portion of the mission is intrinsic to the project – on an equal footing with professional and amateur astronomy research. "I want the telescope to reach out to the classroom, to interested people at home, to lifelong learners," says Victor Krabbendam, the telescope's project manager.

ABOUT THE WRITER

Eagle Gamma is a writer specialising in astronomy and astrophysics. He is writing a book, *Astrotripping: A Cosmic Joyride.*