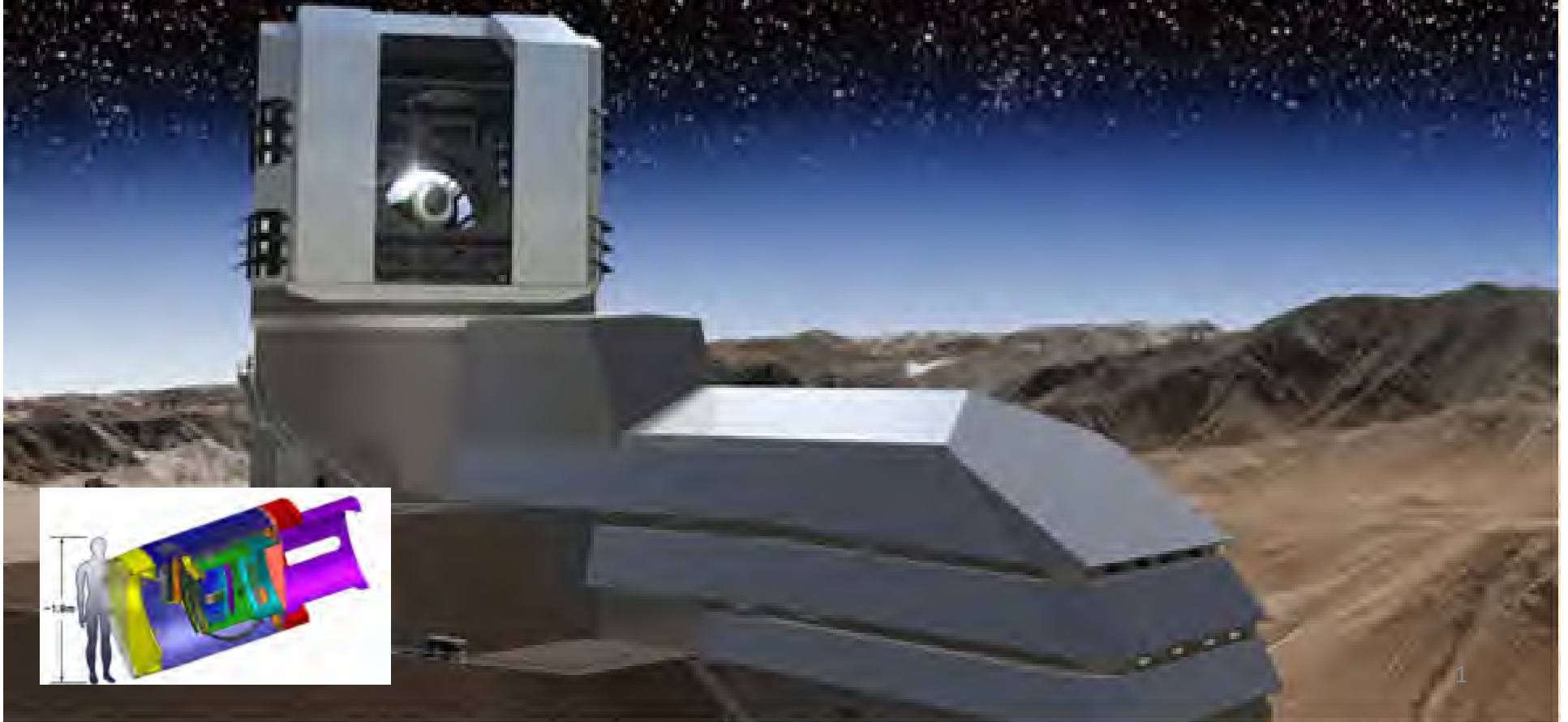
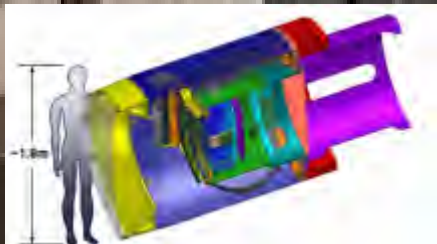


# LSST: Creating a “Digital Universe”



# LSST: Creating a “Digital Universe”

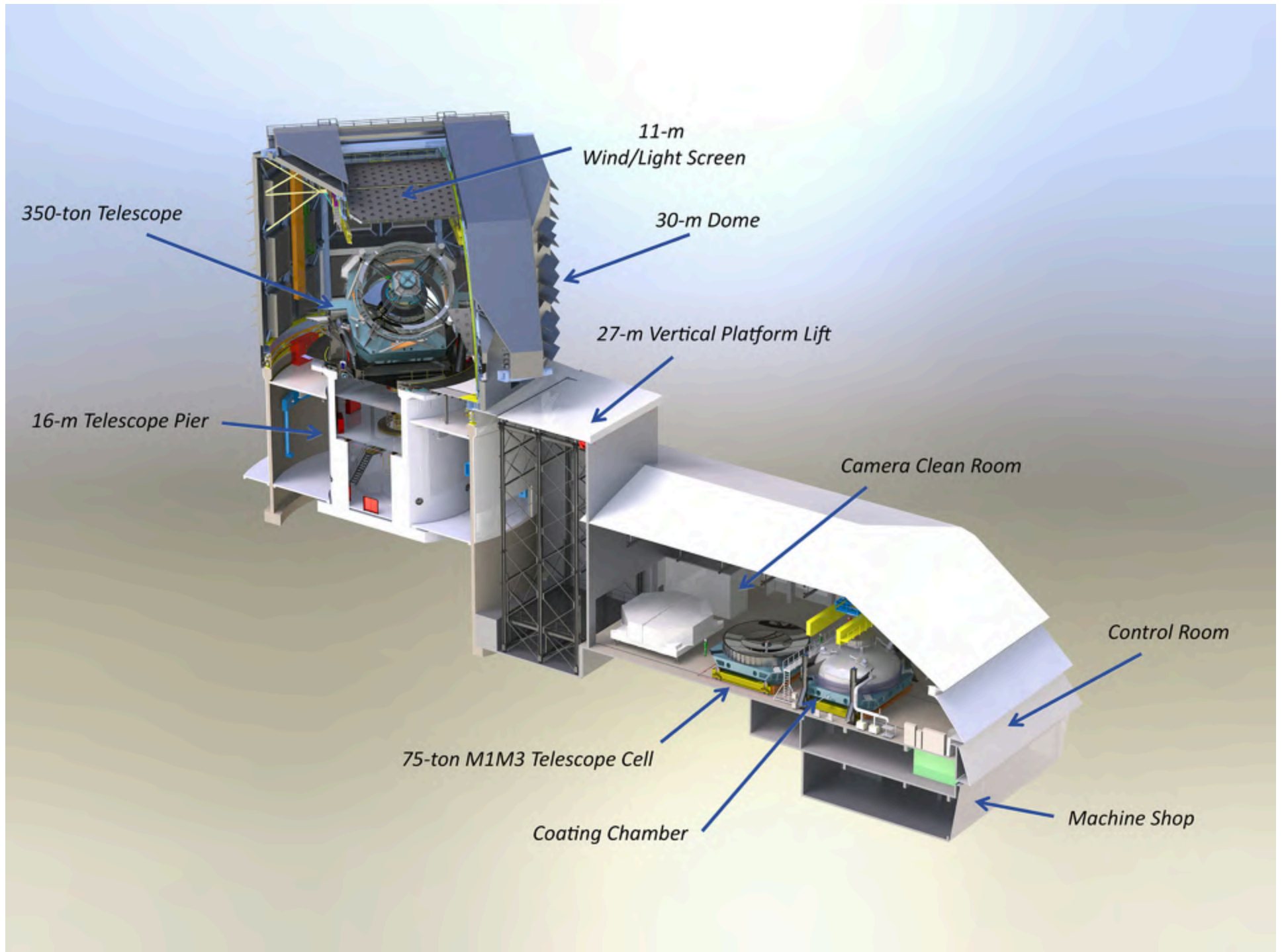
LSST is designed to image the whole sky every few nights for 10 years, giving us a movie-like window into our dynamic Universe.



# A NEW WAY OF OBSERVING

Preparing for the widest, deepest, fastest eye of the new digital age

- Large Synoptic Survey Telescope (LSST)
  - 8.4m telescope + 3.2 gigapixel camera
  - 12 GB per image, an image every 20 seconds
  - 15 to 30 TB collected per night; full sky coverage every few nights
  - REAL TIME processing:
    - Transfer to data center in U.S. in <5s
    - Each image processed within 60s, alerts on any changes
    - Roughly 10 Million alerts per night



# Construction Progress



# Building taking shape



# Base Facility Design (La Serena)

- Provides LSST+NOAO+AURA requirements
  - New offices, laboratories,
  - Data Center, and public spaces.

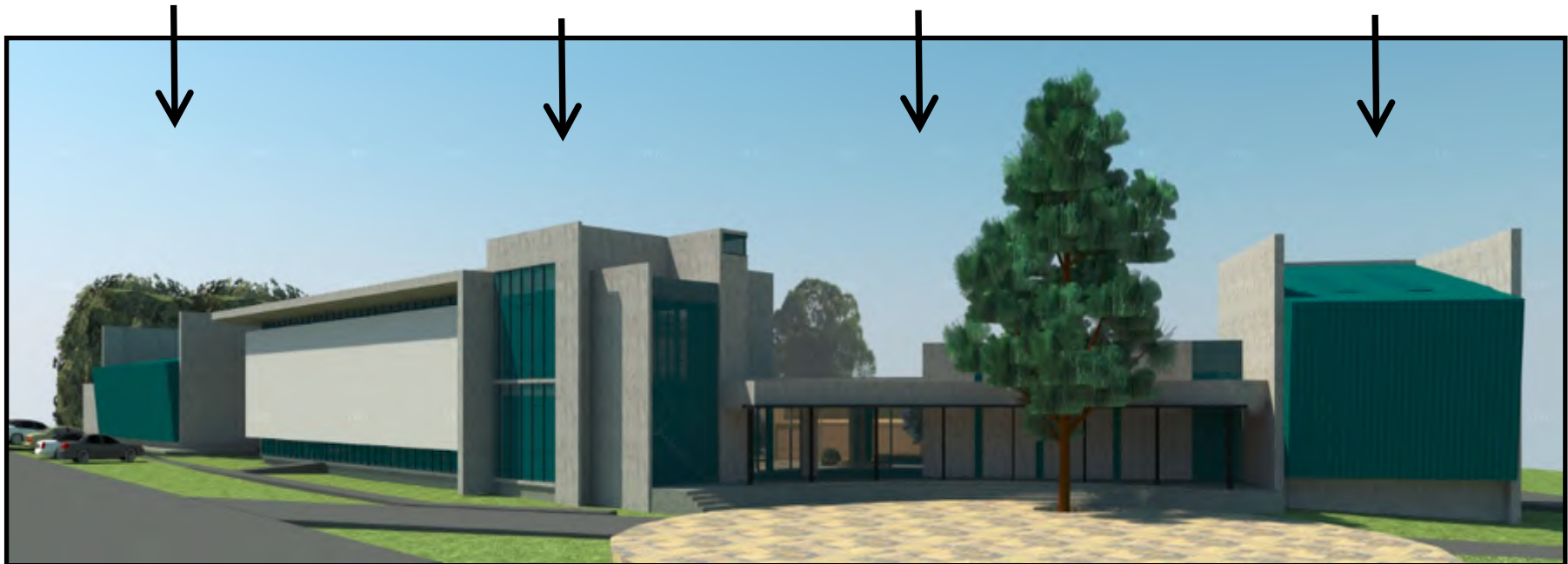


New Data  
Center

New Office  
Building

New Main  
Entry

New Public  
Gallery

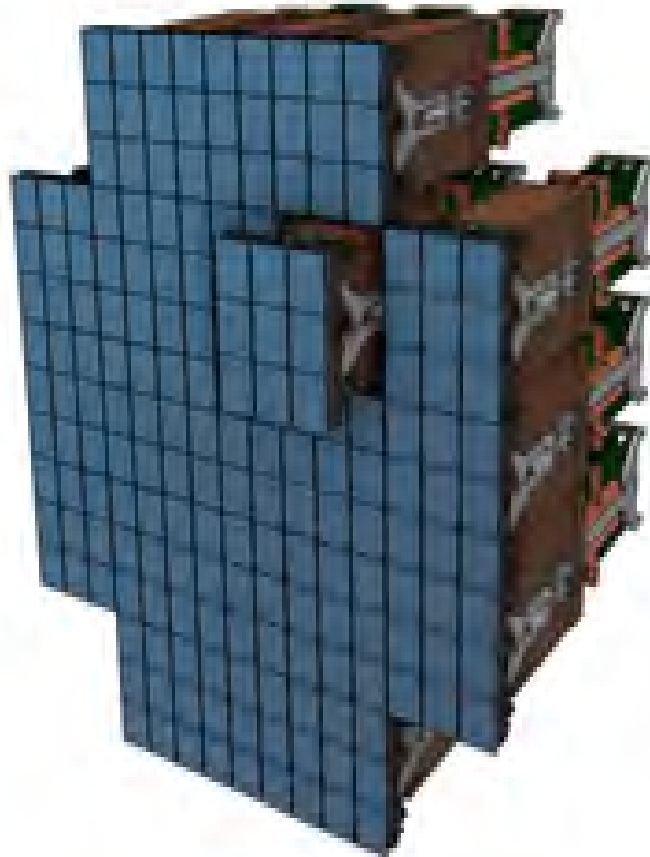


North Elevation of New Base Facility Addition

*Barr– LSST 2016 workshop*

# LSST Camera

- 3.2 billion pixels!

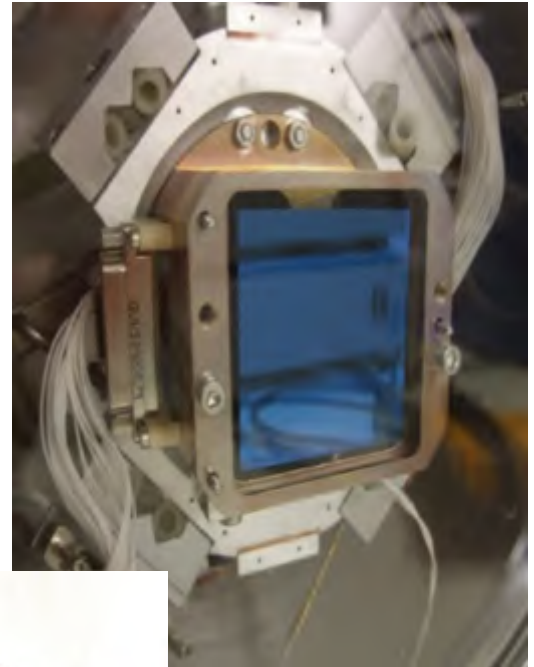


*Reil – LSST 2016 workshop*



# Sensors

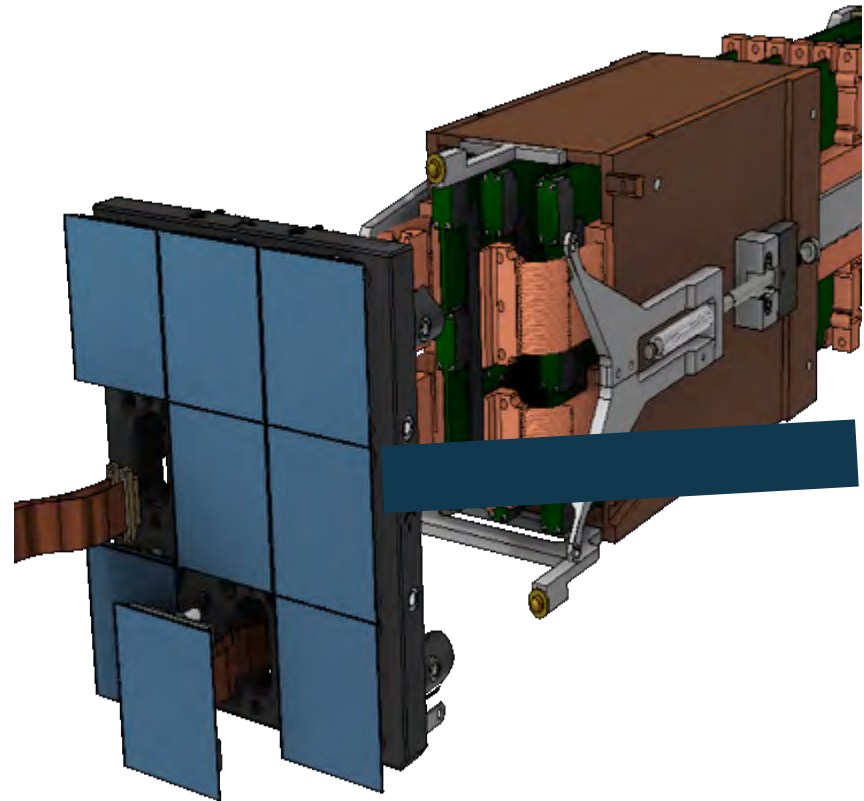
- 16 total accepted devices
  - Many more in pipeline
- Two vendors
  - devices accepted from each
- Each sensor 16 MPix



*Reil – LSST 2016 workshop*

# Science RAFTs

- Combine 9 sensors in a 3x3 array
- 144 Mpix camera
- All readout electronics behind the sensors
- First engineering unit (of 2) assembled/delivered this fall
- First Science RAFT delivered to I&T by spring 2017



# Cryostat Grid

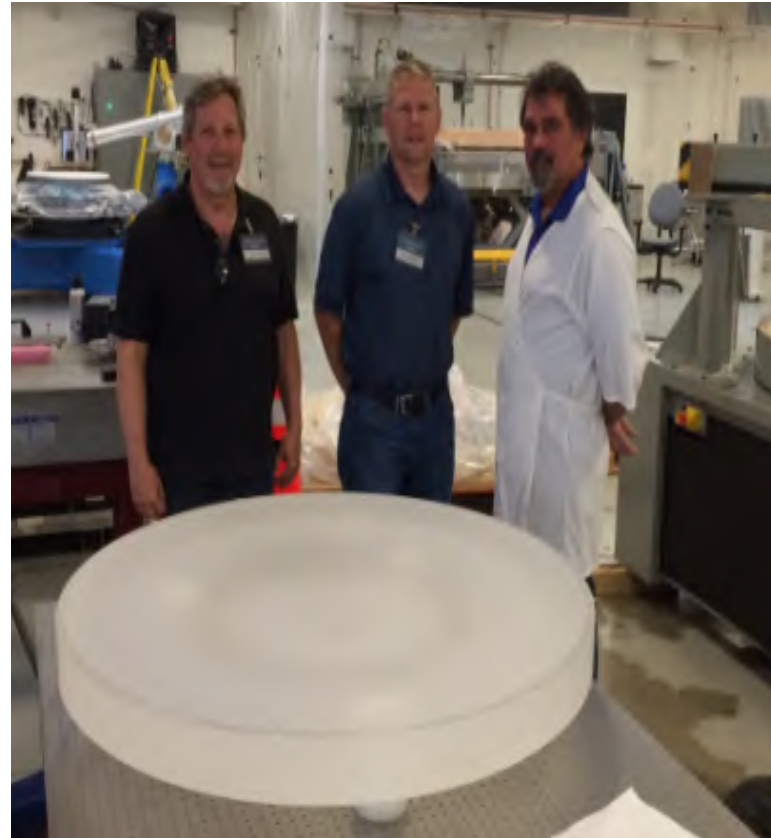
- RAFT and corner RAFT towers are installed into the Cryostat grid
  - At SLAC soon!



*Reil – LSST 2016 workshop*

# Camera Optics

- All the big pieces of glass are in place
  - AOS, Vanguard, BATC – L1/L2
  - TCC/SESO – Filters/L3
  - Materion – Filter Coatings
- L1 is over 5 feet in diameter!
- All the filters will be fully characterized by the vendor by direct measurements on the actual optics across the entire aperture.



*Reil – LSST 2016 workshop*



- Data Management
  - Major Data Center in U.S. (Urbana) & Chile (La Serena)
  - Internet links of 100Gbps+ for data transfer
  - 100s of petabytes in archives and DB
- Data Processing & Analysis
  - Advanced Pipelines: No human intervention possible, given data volumes and real time requirements
  - Machine learning needed for analysis: separating real signal from false positives in billions of objects
- ***Many of the same requirements of other data-intensive fields, in both academia and industry***



# Strategic Operational Partnerships

Developing methods to mine, analyze, and understand LSST data

- Connectivity @100Gbps+
  - High-speed Chilean bandwidth (**REUNA**)
  - International bandwidth (**AmLIGHT, RedCLARA**)
- Distributed Computing Systems
  - Supercomputer center(s) to provide bulk storage, large scale processing (e.g., **NCSA, IN2P3, NLHPC, PUC, Others**)
  - Effective access to data products through Data Access Centers (DACs)
  - Grid processing, high-performance storage, advanced DBs

Goal: Provide **effective** access to data products and analysis resources for scientists as well as public users

# A Data Stream, a Database, and a (small) Cloud

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.
- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion single-epoch detections (“sources”), and ~30 trillion forced sources, produced annually, accessible through online databases.
- Deep co-added images.
- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

Nightly

Release

User

# State of the Pipeline: Overview

- It's State of the Art: this is the highest-quality *general-purpose, general-dataset* pipeline in astronomy.
  - It's not the best *single-purpose* pipeline: customized SExtractor+X runs can do better for weak lensing or detecting high-z objects, etc; DOPHOT can do *much* better in crowded fields.
  - It's not the best *single-dataset* pipeline (compare to e.g. SDSS Photo and PanSTARRS IPP).
- LSST needs to build a general purpose pipeline: one catalog to rule them all.
  - This is hard: different science cases prefer to make different mistakes.





# Strategic Scientific Partnerships

Developing methods to mine, analyze, and understand LSST data

- Scientific Analysis Challenges:
  - Automatically finding unique objects: one in billions
  - Separating small signals from systematic effects
  - Limiting, if not eliminating, false positives in multiple dimensions (time, space, color, etc.)
  - Combining peta-scale datasets in complex ways
- Requires techniques that deal with both **quantity** and **quality** of data
  - Partnerships with **university researchers in U.S. & Chile, CMM, MAS, & others**
  - Many challenges in common with other fields



<http://www.noao.edu/meetings/lst-oir-study/>

# Key Recommendations

- Support OIR system infrastructure developments that enable efficient follow-up programs
  - Multiplexed wide-field MOS on 8-m
  - Moderate resolution OIR spectrograph on 8-m
  - Other (larger and smaller) telescope resources
- Ensure the development and early deployment of an alert broker, scalable to LSST
- Study and prioritize needs for computing, software, and data resources
- Continue community planning and development



## “Towards Science in Chile with LSST” 2016

**Viña de Mar, Chile, December 12-13, 2016**

Based on the success of the first LSST-Chile Workshop on Nov 19-21, 2015, we are now organizing the second version of what hopefully will become a yearly activity: the "Towards Science in Chile with LSST" 2016 workshop. The main motivation for this workshop is to address how prepared are we, as Chilean community, for the avalanche of LSST data and more importantly what research we hope to do with these data. With this in mind, we are organizing a two-days meeting in which members of the Chilean community can present and discuss their ideas to make the best use of the LSST data and multi wavelength follow-up studies, ranging from solar system and planetary science to high redshift galaxies and cosmology.

There will be invited talks (speakers TBD) by key LSST players to provide context and further information, including chairs from the LSST scientific collaborations. A significant fraction of the workshop will be devoted to preparatory science, data management, access, computing needs, resources, Chilean representation on LSST panels, etc.

The meeting will take place in Viña del Mar, at the [Best Western Marina del Rey](#) Hotel. The Workshop will start in the morning of Monday, December 12, 2016 and finish on the afternoon of Tuesday December 13, 2016. There will be no registration fees for the workshop. Coffee breaks, lunches and dinner on Monday will be provided free of charge for all participants. In addition, young scientists presenting work related to LSST can apply for financial support to attend the workshop. Graduate students already working on LSST-related projects applying to present their work at the meeting are strongly encouraged to apply for travel support from SOCHIAS on the October or November calls.



- Data available to all scientists in Chile+U.S. and other member institutions
  - Strengthening undergrad and graduate programs
- Data in schools
  - Data enabled programs for K-12
  - Real data for early research experiences
- Citizen science
  - Public participation in classification and discovery
  - Materials for Planetariums and Museums

# LA SERENA SCHOOL FOR DATA SCIENCE 2017-2021

## Applied Tools for Astronomy

## + Bioinformatics

AURA Campus  
La Serena - Chile



- Training the next generation of scientists in fields of astronomy, bioinformatics, mathematics, computer science, etc., in the tools and techniques of “Big Data”
- International program: funding for students from Chile and the U.S., with space for additional international students from other countries
- Target students: senior undergraduate and beginning graduate students

[http://www.aura-o.aura-astronomy.org/winter\\_school/](http://www.aura-o.aura-astronomy.org/winter_school/)

# EPO Executive Summary



**LSST STEM EDUCATION & PUBLIC ENGAGEMENT**  
LSST Project Office, 855 N. Cherry Avenue, Tucson, AZ 85721 [www.lsst.org](http://www.lsst.org)

**LSST is a new way to observe:**  
Wider, Faster, Deeper Eye of the New Digital Age  
23 billion stars, 10 billion galaxies, "20" alerts per night  
Run multiple simultaneous investigations from public citizens

LSST data will be widely accessible, and discovery opportunities will be available to students and the public as easily as to the professional astronomer. The project design is integrated with the science mission of LSST, aligned with national priorities and responsive to audience need.

LSST Education and Public Engagement takes advantage of emerging trends:  
Increases in bandwidth  
Increased use of social networking  
Paradigm shift in use of internet  
Increased appreciation for thinking, free-choice learning

By number, non-specialists are the majority of LSST users. Interfaces are provided for different audiences to become actively engaged in science discovery and LSST.

An innovative **Citizen Science** program will involve people of all ages in LSST discoveries through the visual inspection of alerts: Zooniverse has over 750,000 registered users participating in online projects today!

Authentic research experience is a life-changer for many and the way to hook non-students into science! We'll provide online research projects in a collaborative environment along with face-to-face workshops for instructors.

For all audiences, a **dynamic multi-media web portal** to engage, inform, and personalize where individuals interact with real LSST science data and monitor changes through a range of opportunities.

**Science Centers** will receive access to an open multimedia repository with continuously updated material for content creators. 33 million people visit US planetariums each year!

Realizing we can't do it all, LSST Education and Public Engagement will build **sustainable partnerships** to maximize the impact of our efforts including those that proactively engage underrepresented populations to our programs.

<https://www.lsstscience.org/>  
\* See Sci Edu (2016) 9:1213-1216  
\* <http://www.lifelinespublications.com/reference/lifelines/lifelines.html>

Logos: LSST, ALMA, ENERGY, SLAC, LSST

“LSST data will be widely accessible, and discovery opportunities will be available to students and the public as easily as to the professional astronomer. The project design is integrated with the science mission of LSST, aligned with national priorities and responsive to audience need.”

Interfaces are provided for different audiences to become actively engaged in science discovery and LSST: **General Public, Citizen Science, Classroom Research, Informal Education**

<http://ls.st/ge7>

*Emmons – LSST 2016 workshop*

# LSST Project Timeline

