

The Large Synoptic Survey Telescope (LSST) Construction Status The System is becoming Real

Victor L Krabbendam
LSST Project Manager

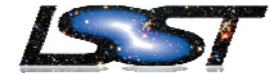
20 September 2018



LSST Status • Brazil • September 20, 2018



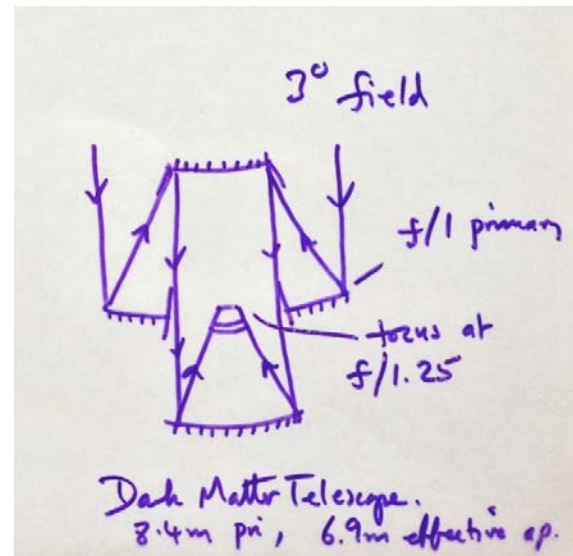
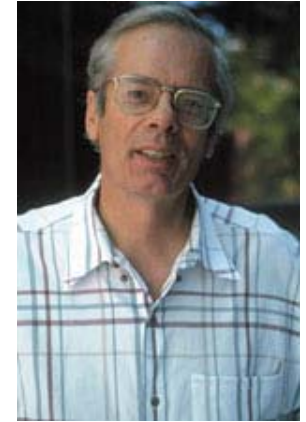
The LSST dream started in mid 90's



Tony Tyson – UC Davis:
Dreamed of an all sky
survey to explore Dark
Matter and the time
domain

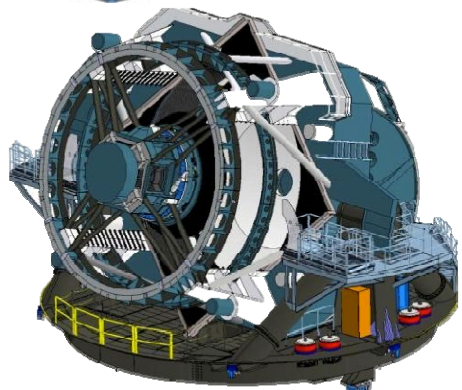


Roger Angel – U Arizona:
Dreamed of an optical
design for large wide-field
telescope

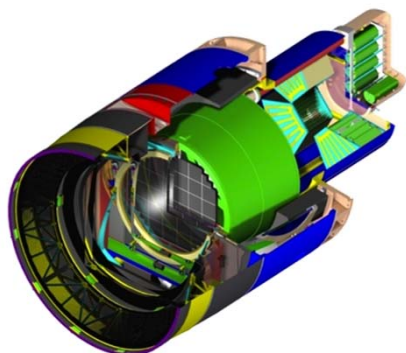




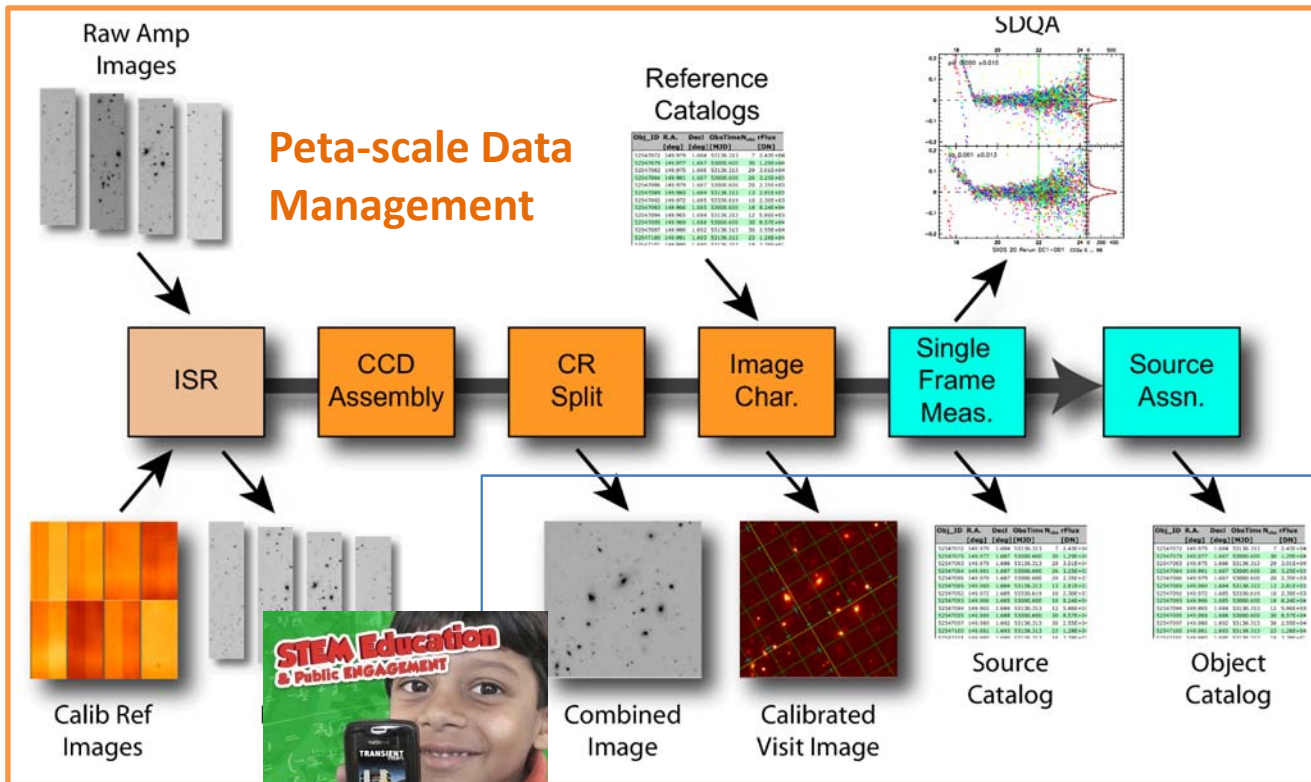
To build an observing facility, conduct 10-year survey, process, archive, and serve images and data products



8.4m Telescope



3.2Gpix Camera



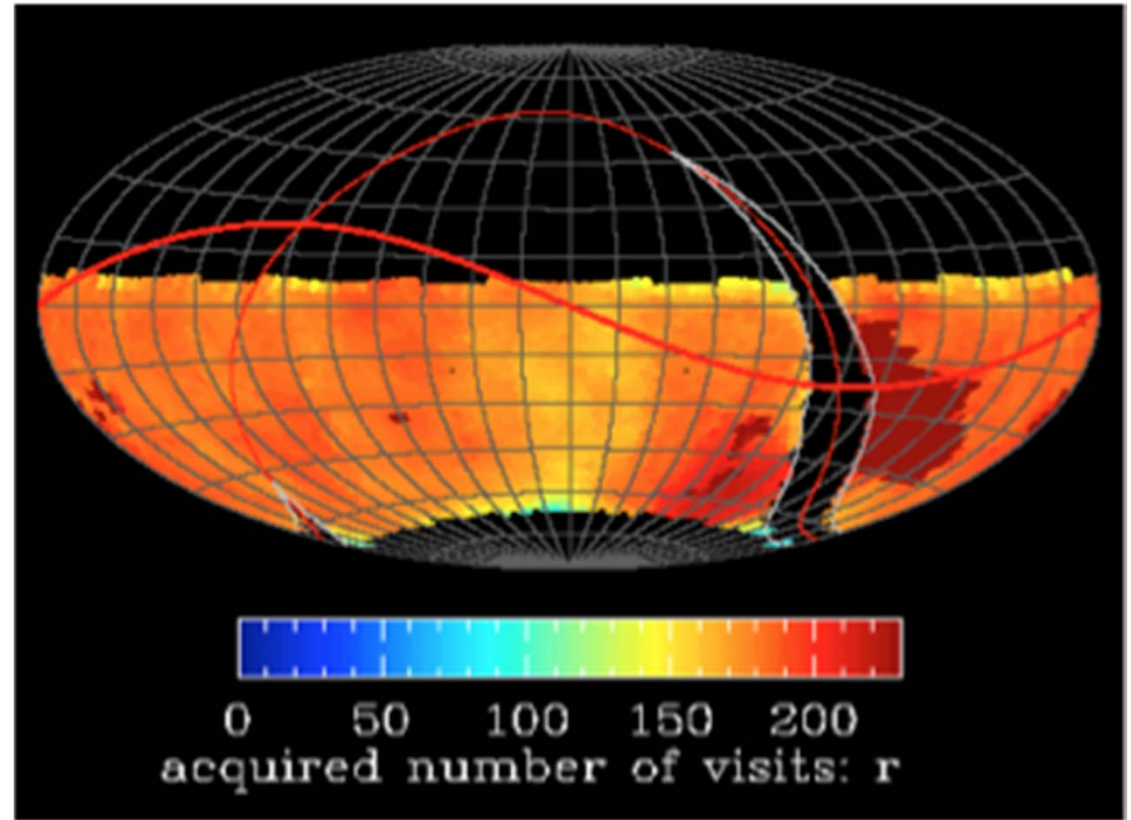


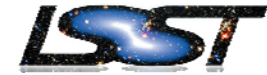
LSST's survey will be a 10-year log of half the sky



LSST will image the entire Southern sky (18k sq deg) every few nights, taking an image every ~ 40 seconds, for 10 years.

The result: *an 825-frame movie in 6-filter technicolor of every object present*





Construction Funding Partners and Managing Organizations



US\$ 473 M



U.S. DEPARTMENT OF
ENERGY

US\$ 168 M



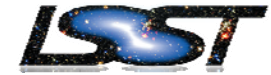
Private, Corporate, and
Institutional Donors

US\$ 30 M





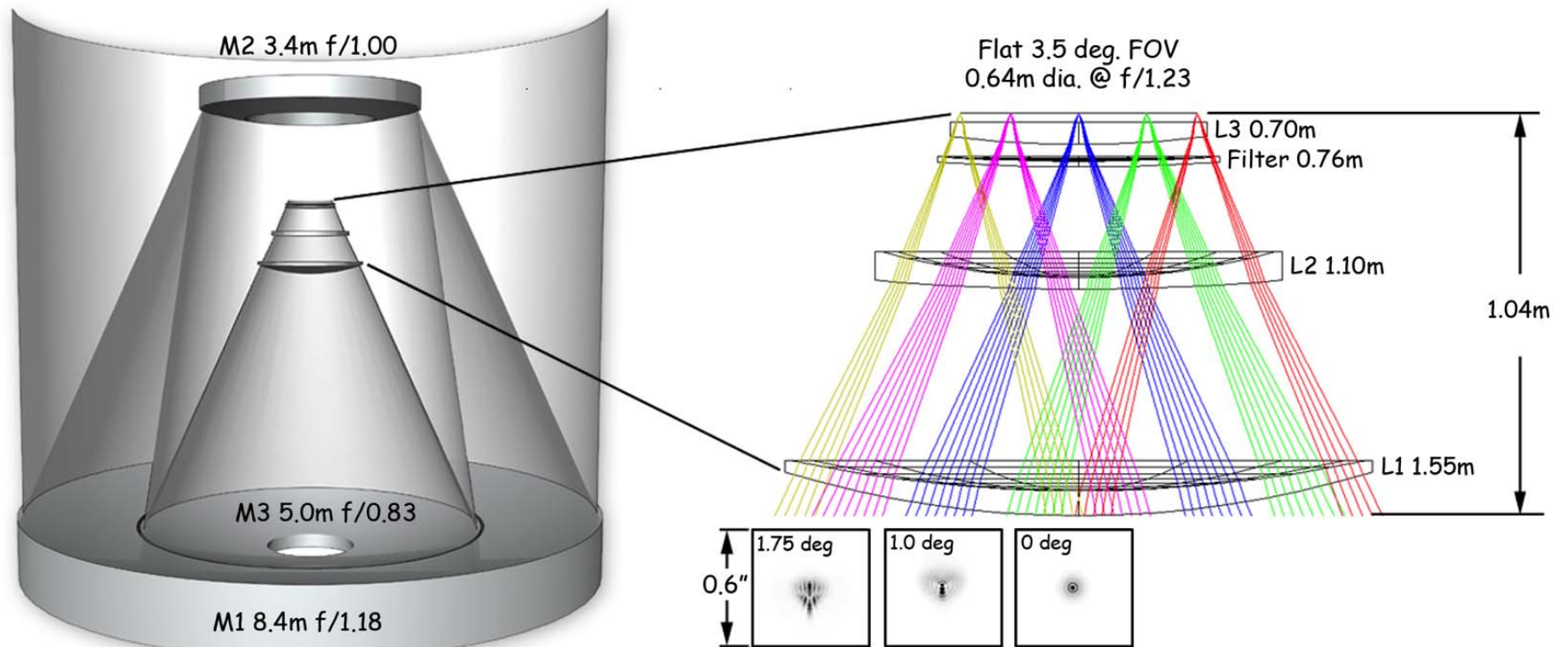
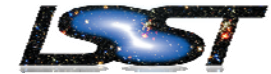
Large Synoptic Survey Telescope (LSST) Status



All Across the Project
efforts are successfully
transitioning to reality



LSST Optical Design

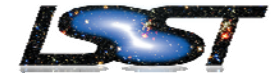


3 mirrors – 3 Refractive lenses – 6 possible filters



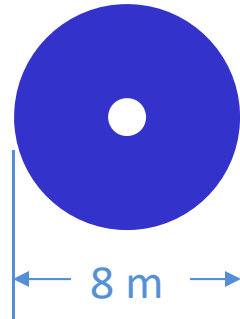


To go wide LSST needs field-of-view



Gemini South
Telescope

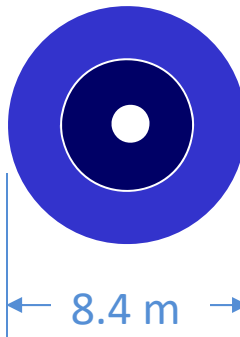
Primary Mirror
Diameter



8 m

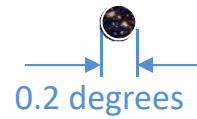


LSST

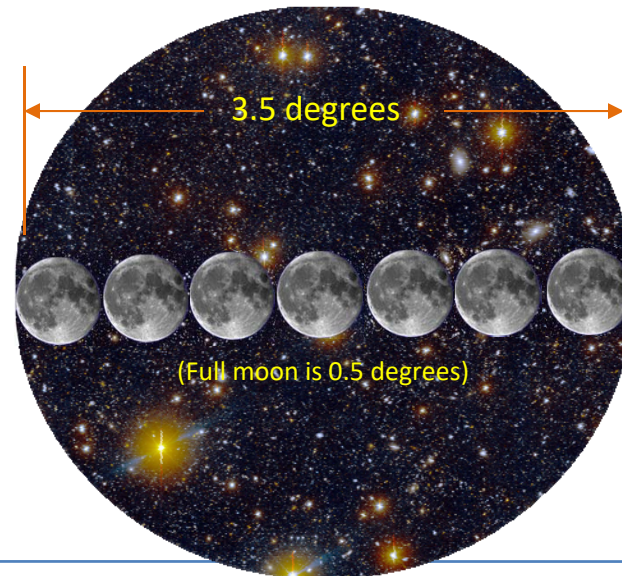


8.4 m

Field of
View



0.2 degrees

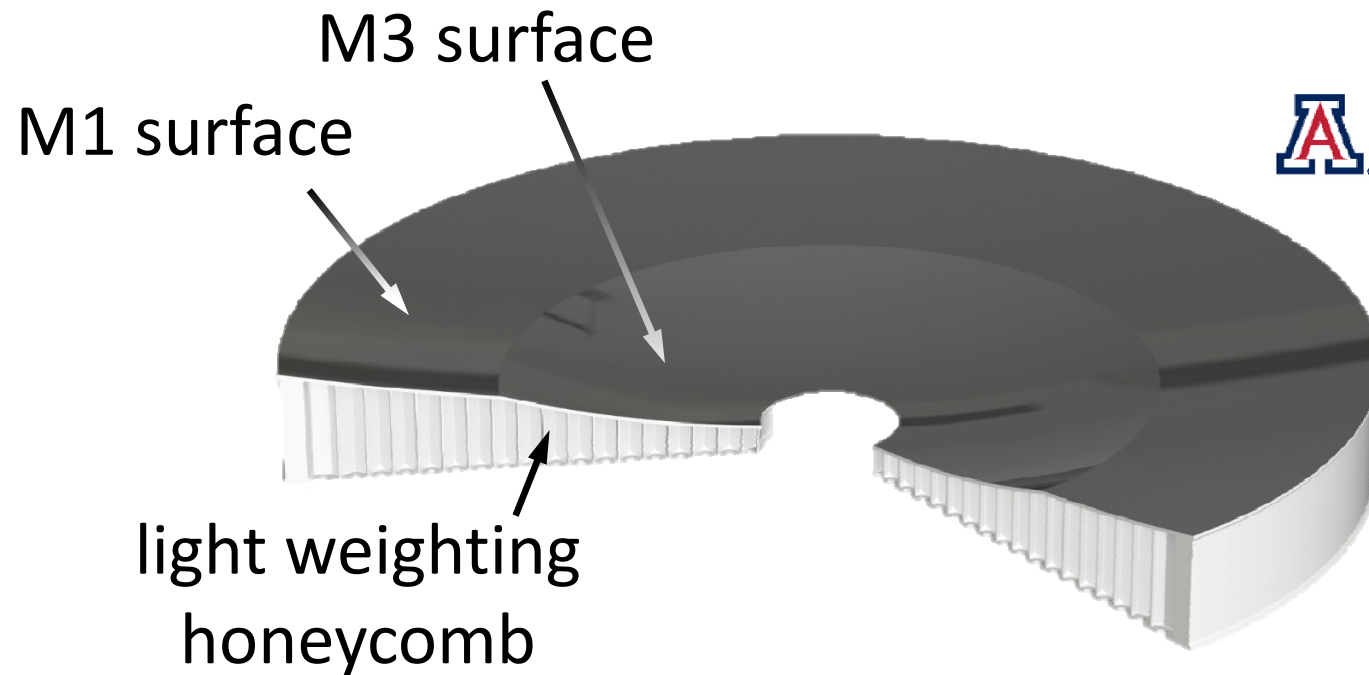
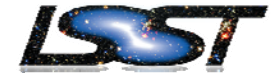


3.5 degrees

(Full moon is 0.5 degrees)



UofA Mirror Lab Technology

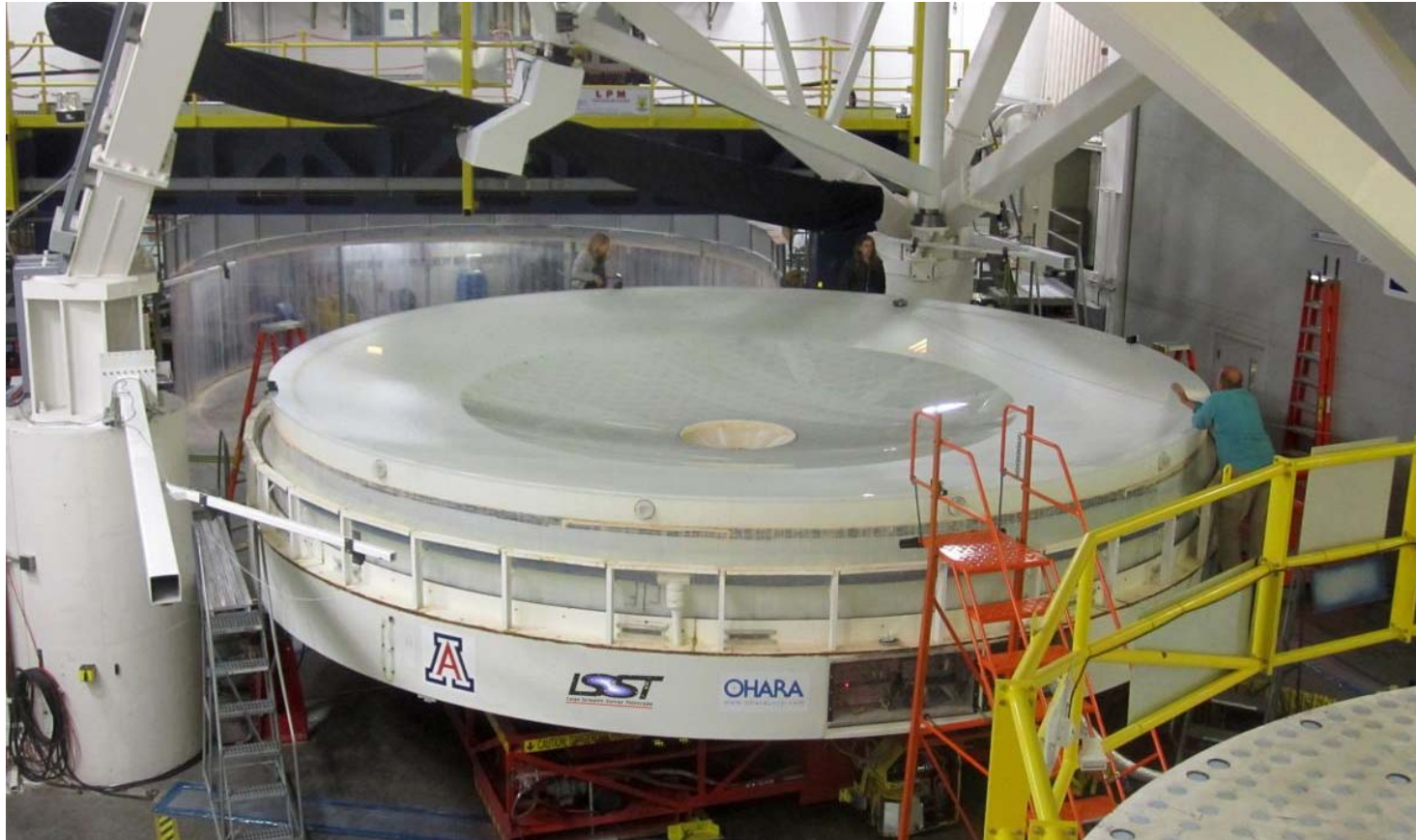
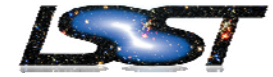


UA SCIENCE
**RICHARD F. CARIS
MIRROR LAB**
Steward Observatory

8.4 m (27.6 ft) diameter mirror



Mirror Polishing Completed in 2014

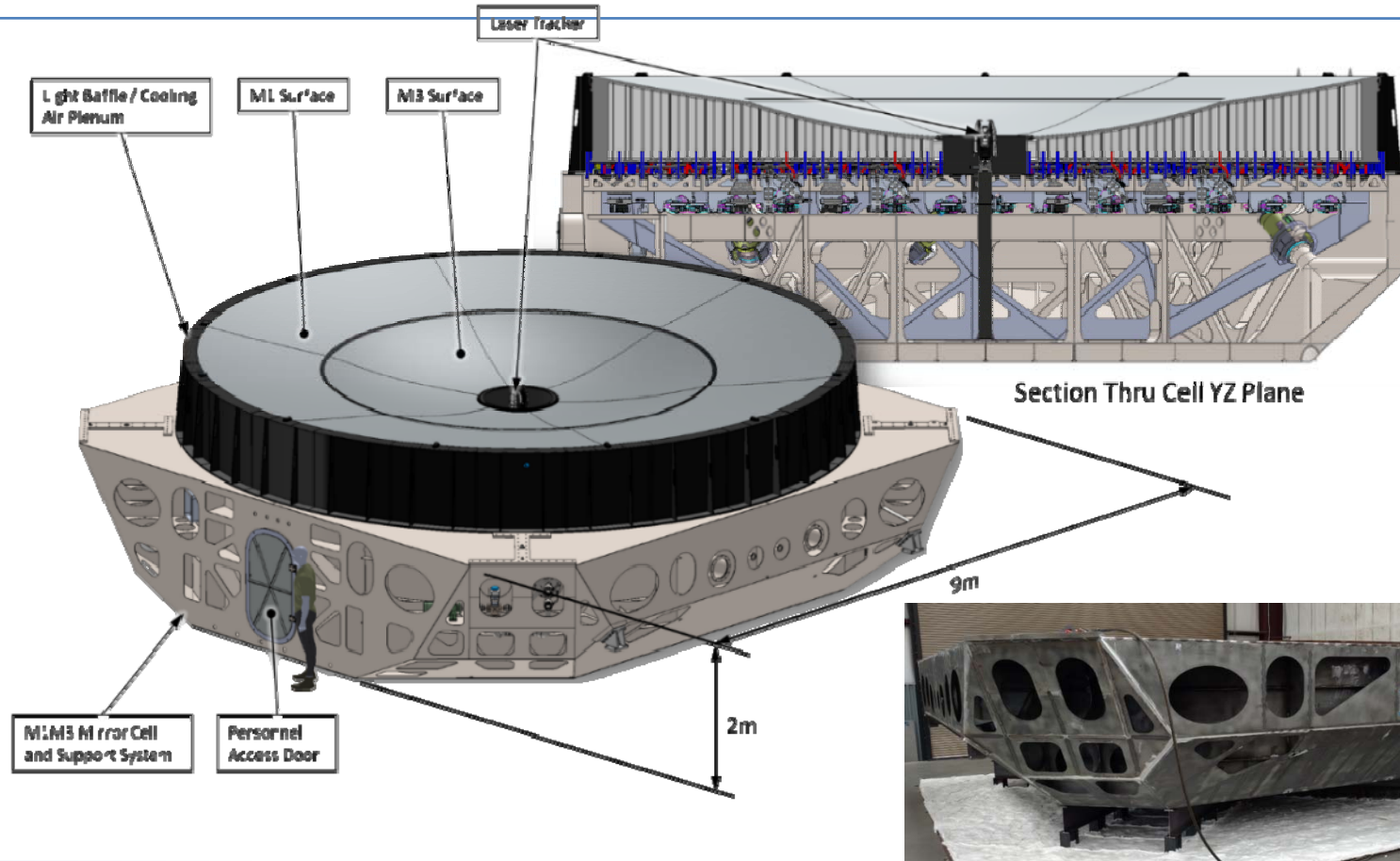
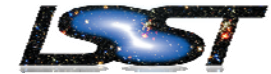




Mirror Moved to
Storage 2015 May 15



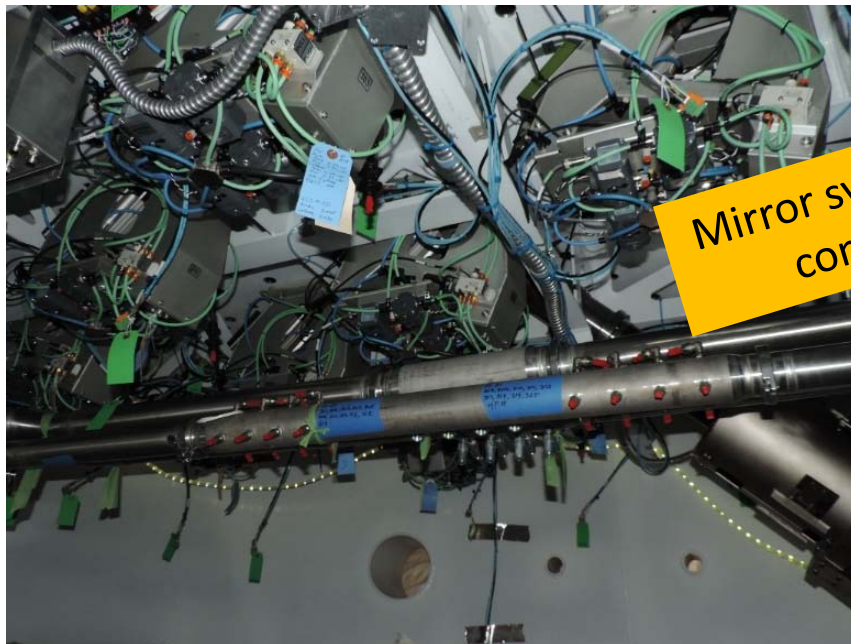
A "Mirror" is Complex Assembly





M1M3 Cell Completed – Surrogate Mirror Testing

Inside the Cell



Mirror system tested under computer control!

Pneumatic actuators, hard points, glycol piping, air piping and electronics installed

Outside the Cell with Surrogate Mirror



Surrogate mirror replicates shape, mass, and first order stiffness of glass

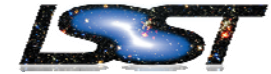
Next step in Plan: Bring mirror back to Richard Caris Mirror Lab,
integrate glass, optical test, and ship to Chile
On Summit – June 2019!



M1M3 when
moved to storage
2015 May 15



3.5m Diameter Secondary Mirror is Completed

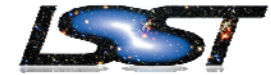


- Corning ULE blank procured early in development phase
- Harris Corporation providing optical fabrication and full cell assembly
 - Final delivery plan: October 2018
 - Shipping to Site for first coating



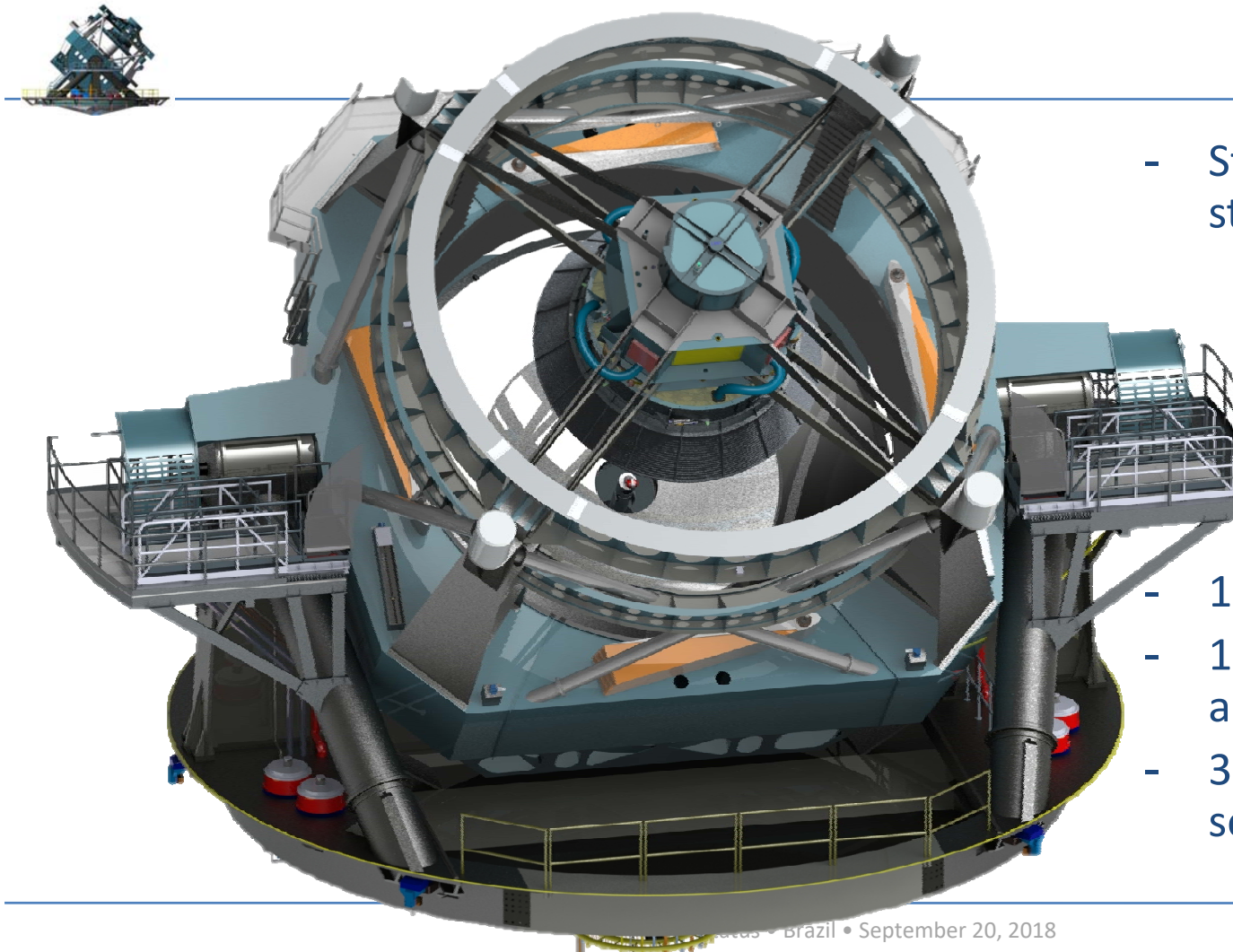


Magnetron Sputtering Chamber Completed



- Coating Chamber Factory Acceptance completed at Van Ardenne - Germany
- Journey to Chile has started.

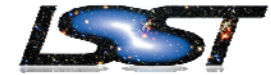




- Stiff 300 ton moving structure
- 10 deg /sec rotation
- 10 deg/sec² acceleration
- 3.5 deg slew-settle: 5 seconds



Telescope mount assembly development by Empresarios Agrupados / Asturfeito

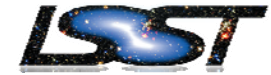


- All major subsystems integrated on factory pier
- All surrogates installed
- Verification of final safety audit
- Now under computer motion control
- Sept/Nov 2018: FOB Aviles, Spain

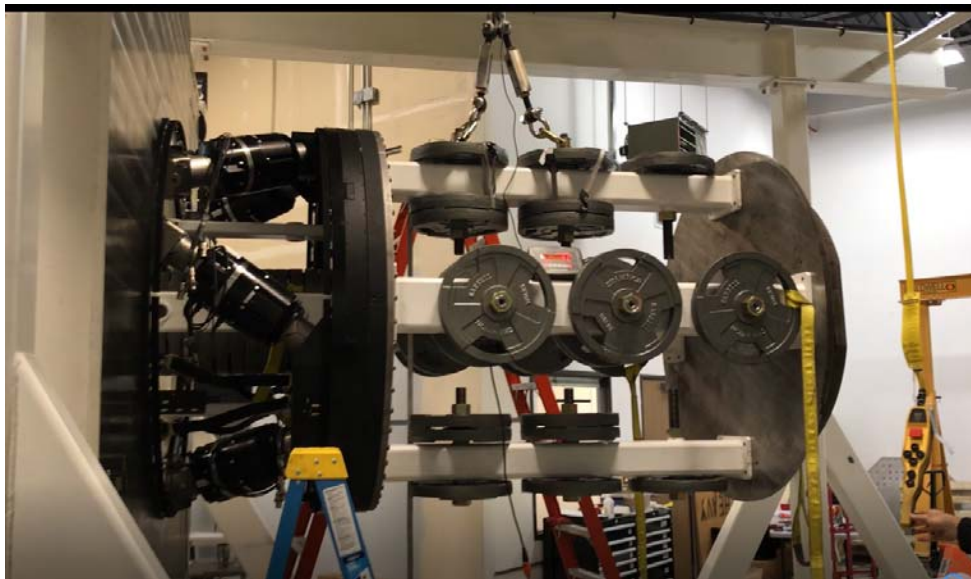




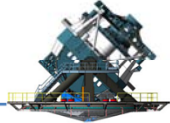
Optical alignment held with Camera and M2 motions



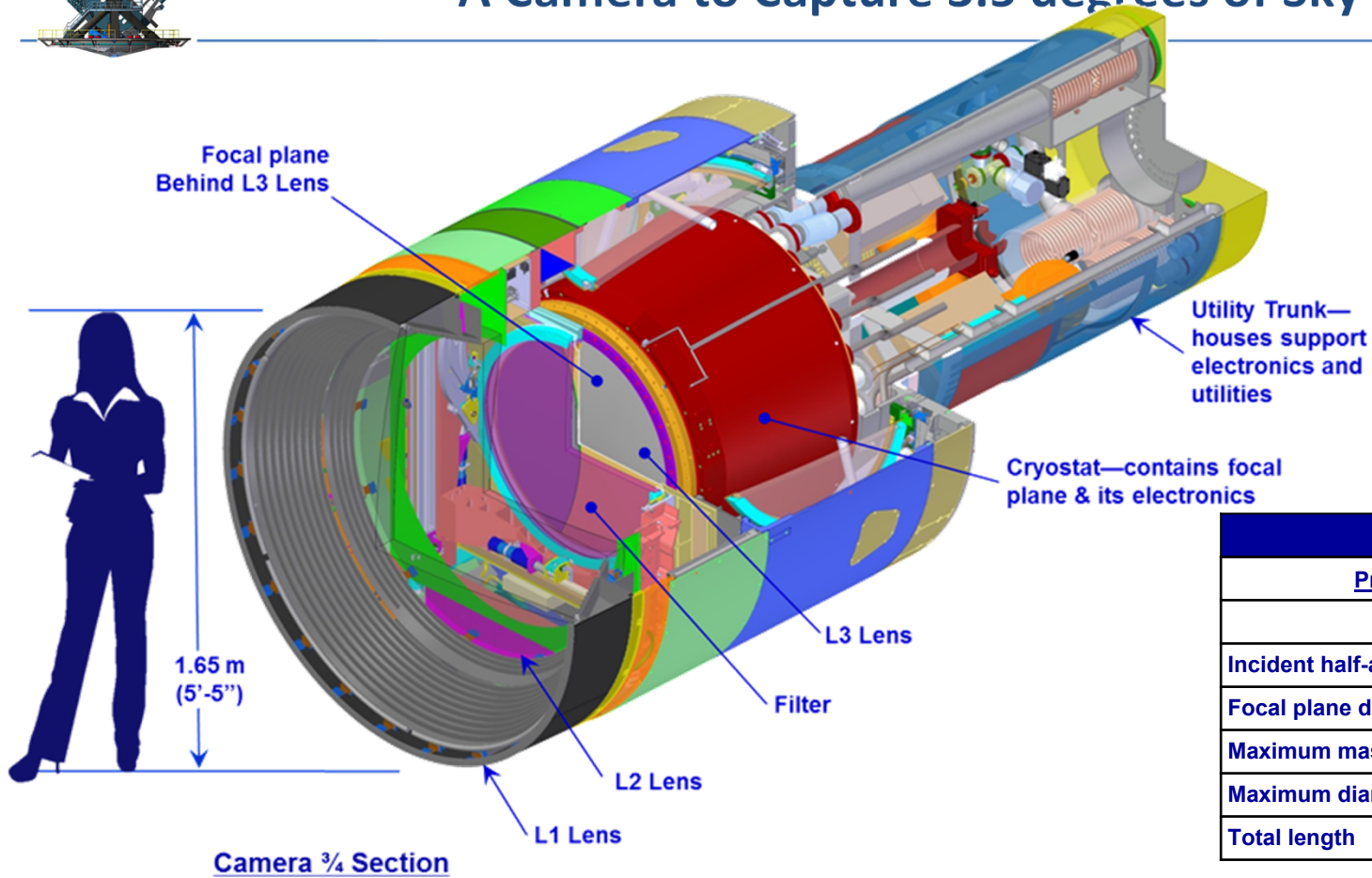
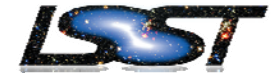
- Camera Hexapod / Rotator and M2 Hexapod being built by Moog – System Delivered August 2018



Successful 200% load test of cantilevered Camera and Integration with LSST software



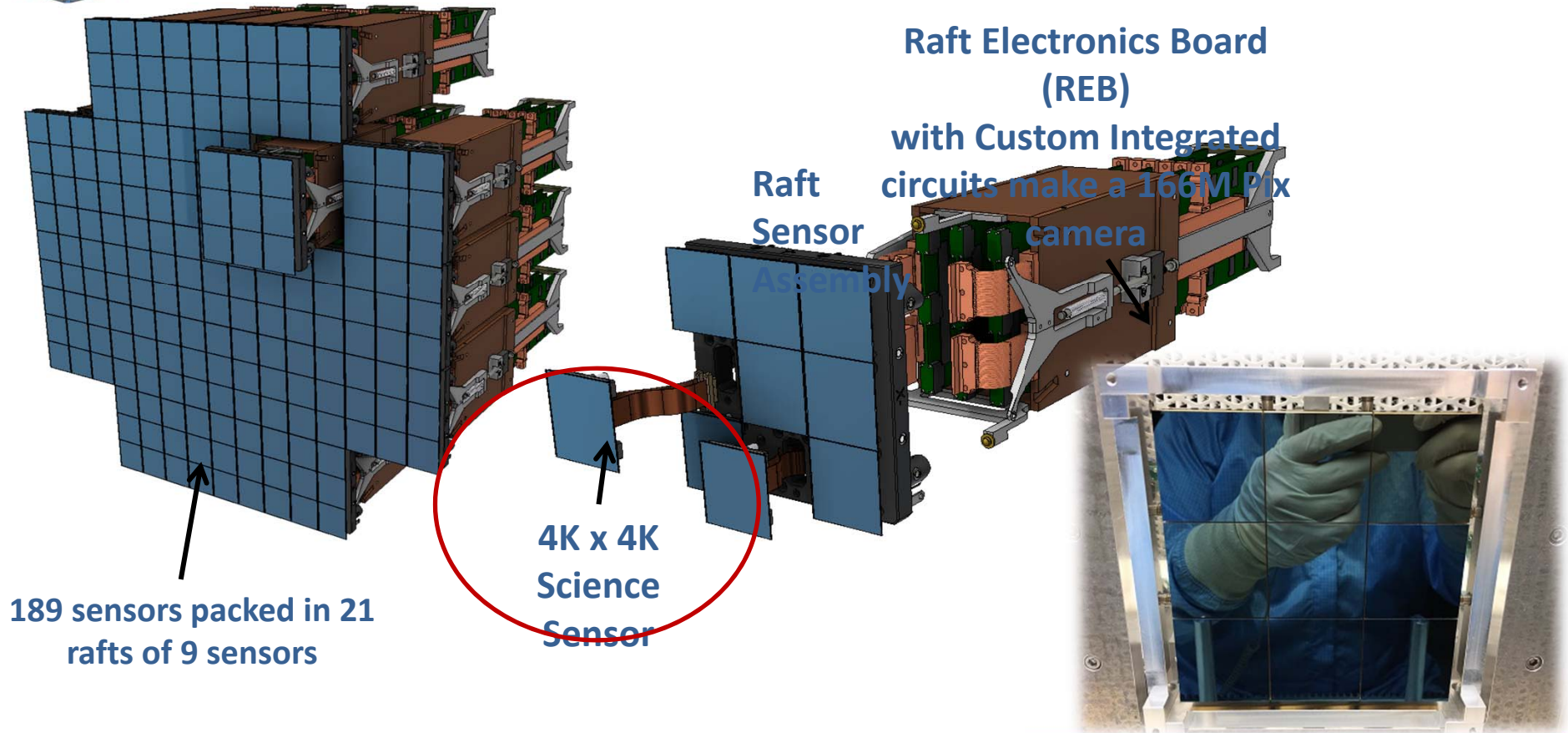
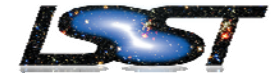
A Camera to Capture 3.5 degrees of Sky



Camera Parameters	
Property	Value
	15 years
Incident half-angle in air	14.2°-23.6°
Focal plane diameter	634 mm
Maximum mass	3060 kg
Maximum diameter	1650 mm
Total length	3732 mm

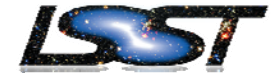


63 CM Diameter Focal Plane with 3.2 GigaPixels

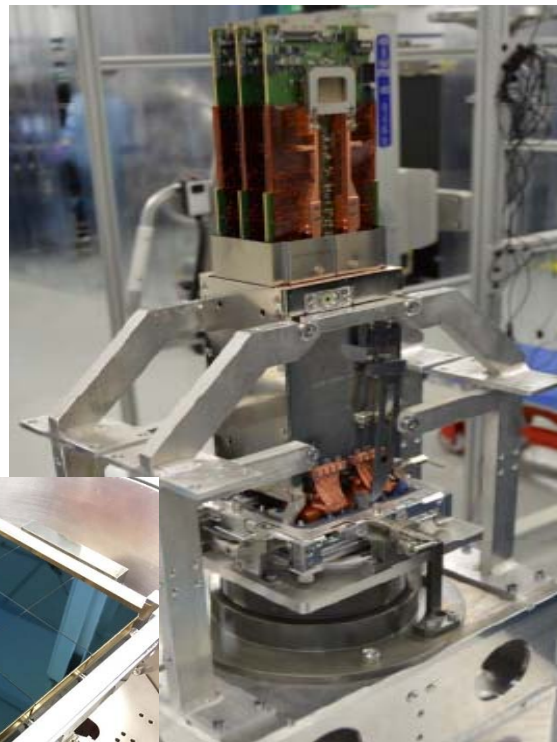
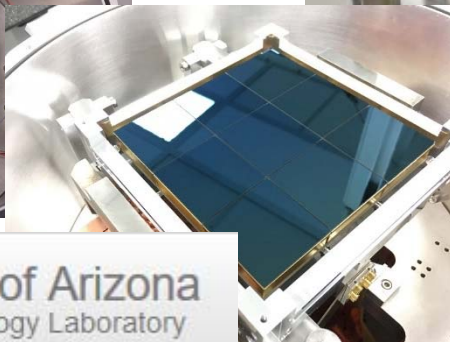
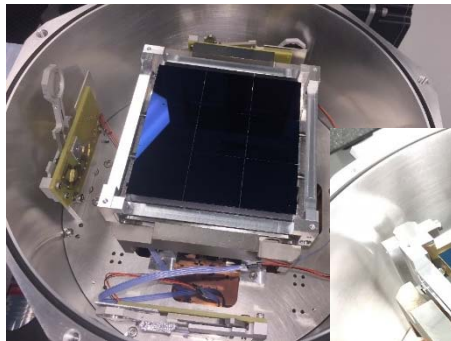




Camera Sensors Fabricated by Two Vendors



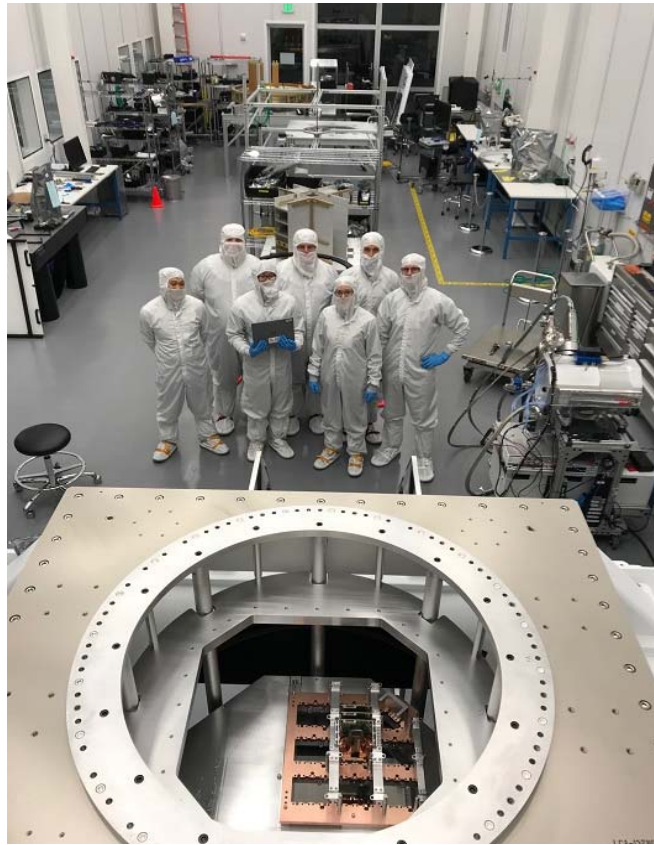
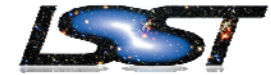
- 274 Science Sensors Delivered
- Need 208



- Brookhaven National Labs does Raft integration
- 12 Rafts delivered
 - 1.6 Gpixels Ready!
 - Need: 21 Science Rafts and 4 corner Rafts
Over half way!

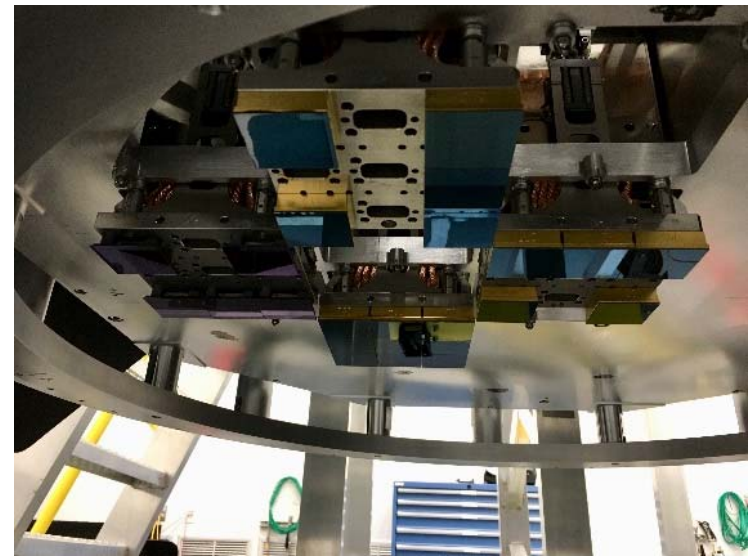


Integration and test activities progress



- Bench for Optical testing assembled and under test
- Raft integration fixture received and under test after performance issue with the 3-axis stage.
- Start of camera integration in the fall of 2018

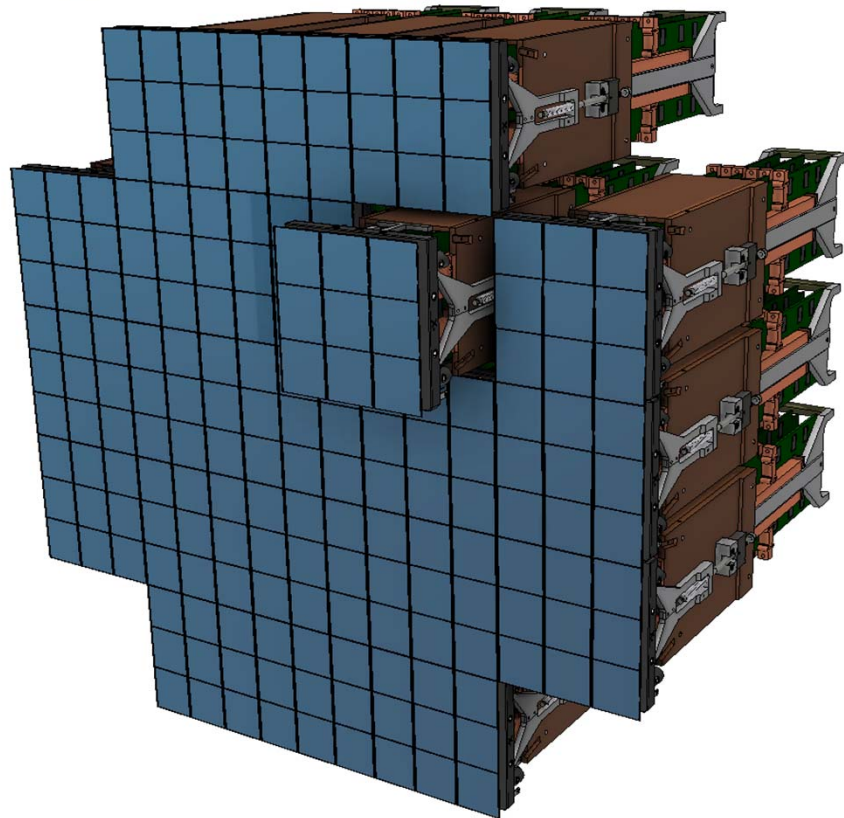
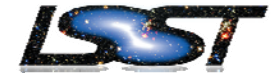
4 mechanical rafts
inserted to verify
integration system



Bench for optical test
with mockup cryostat
and one mechanical raft



Sensor Gaps are Tight - Collecting Efficiency



=

Each raft is slightly more delicate and valuable....

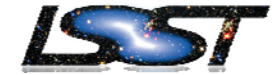


¼ " spacing

¼ " spacing



Cryostat progress (Critical Path)



- HB-Cesic Grid manufactured, cleaned and pre-assembled
- Cryo and cold plate manufactured and assembled
- Vacuum system completed and tested
- Cryostat assembly completed



Cryostat During Leak Testing



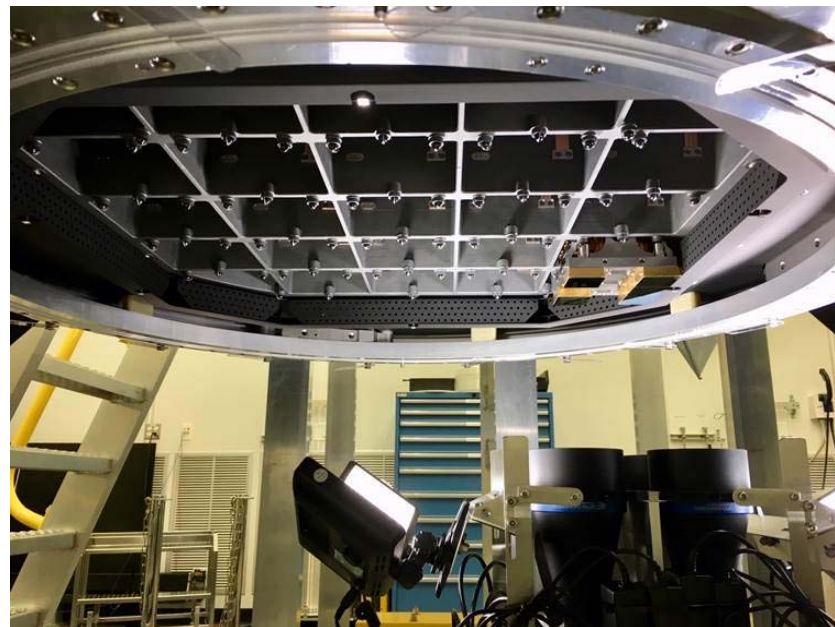
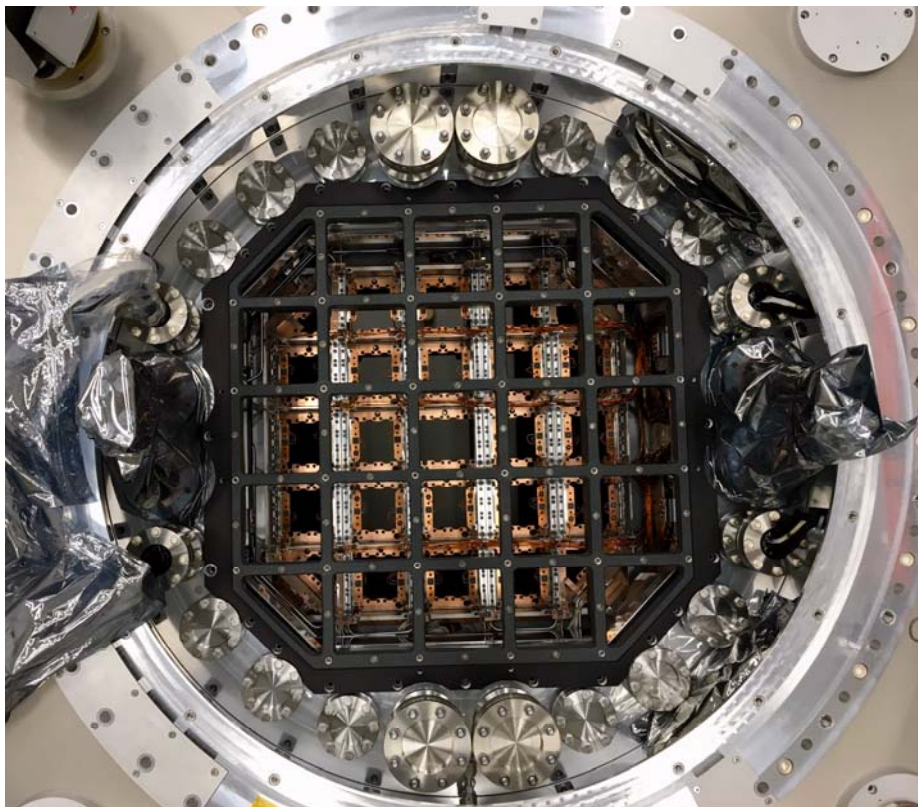
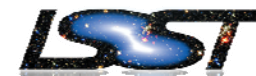
Assembled grid



Assembled cryoplate

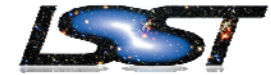


Cryostat Ready for Rafts !





Filter Exchange Systems Complete and Tested



- Collaboration with IN2P3 labs in France for key Camera elements
- Filter Autochanger and Manual loader (6th filter) full size prototype completed and tested
- Carousel full size prototype completed and tested – Only final assembly on camera back flange remains



Filter Autochanger



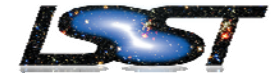
**Filter loader on
transport cart**



5 Filter capacity carousel



Camera Optics Progressing Well



- Ball Aerospace leading L1 and L2 Assembly fabrication
 - Lenses polished at Arizona Optical and accepted for coating
 - L1-L2 composite structure completed
- L2 first surface coated with broad band AR coating at REOSC.



L1 inspection



L2 at coating vendor

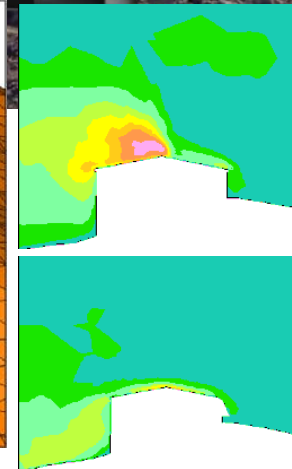
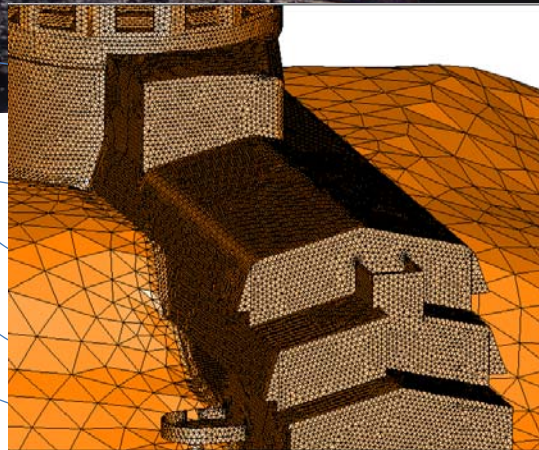
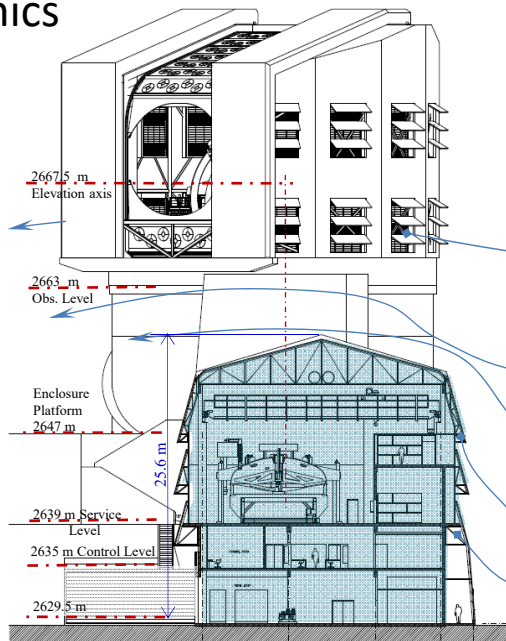
Leading the World in Precision Optics

AOS
Arizona Optical Systems



Summit Support Facility Design will Impact Observatory Performance

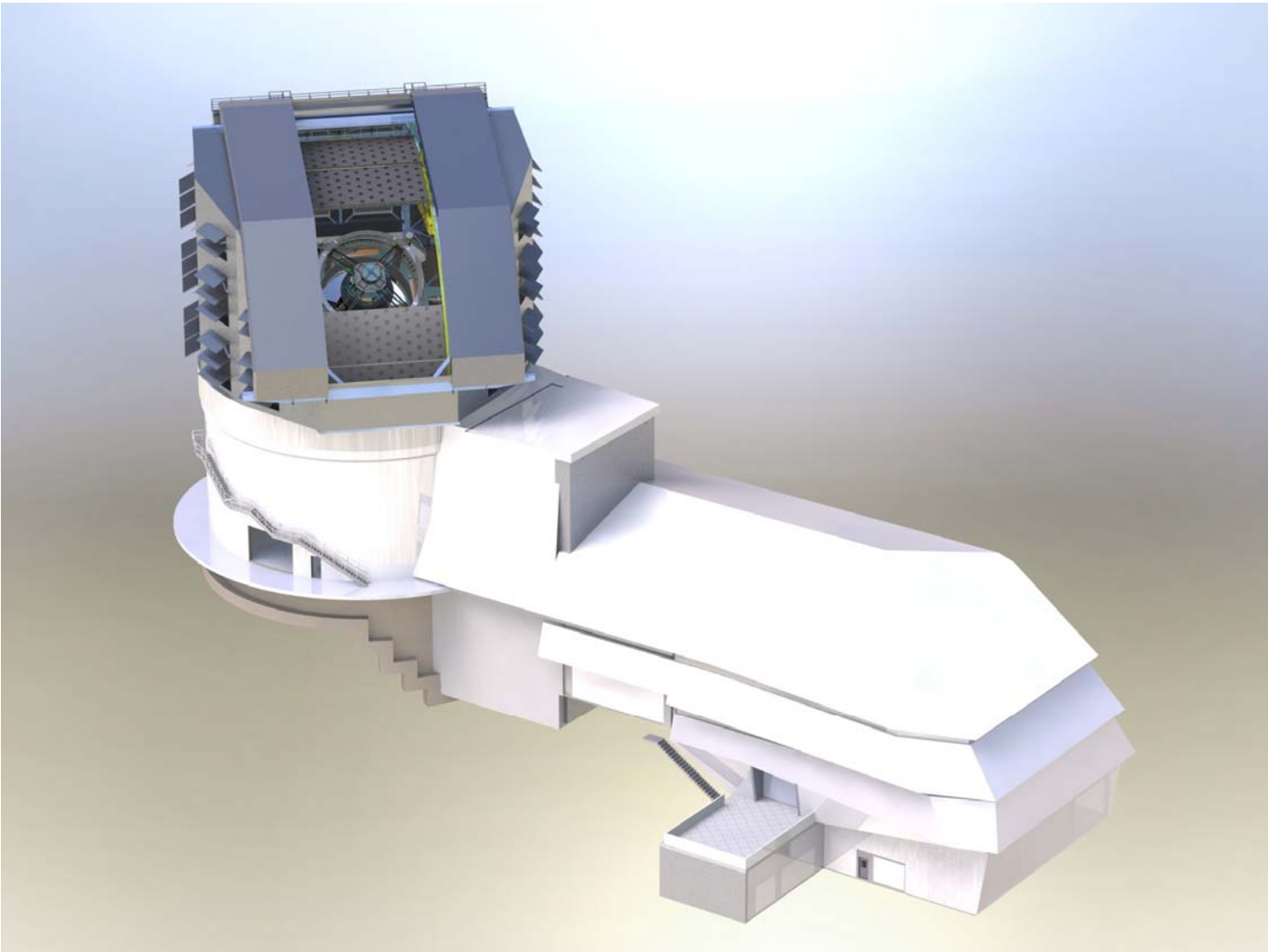
Exterior building composition shaped by topography & aerodynamics



without panels

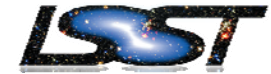
with deflector panels

Computational Fluid Dynamics (CFD) Of Building Site and Dome





Summit Facility on Cerro Pachón

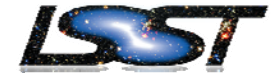


- Summit Facility Substantial Completion achieved by Besalco in February 2018
- Computer room in use and IT infrastructure initiated
- 80-ton Pflow Lift tower completed; lift carriage/mechanism assembly in progress
- European Industrial Engineering (EIE) Dome erection is priority activity – Early 2019 completion expected



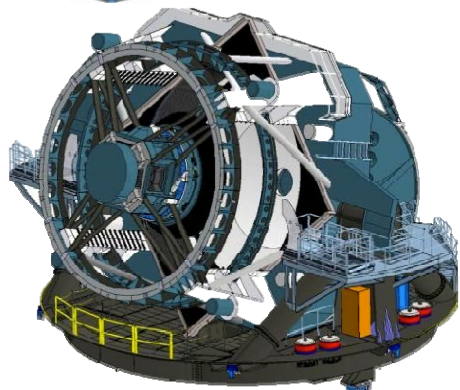


Interior Spaces within Summit Facility

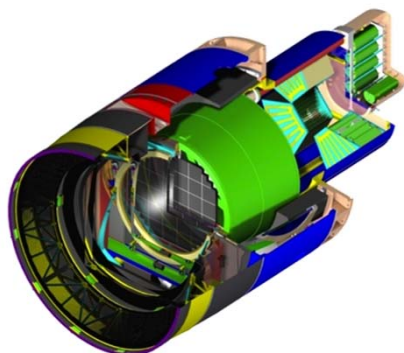




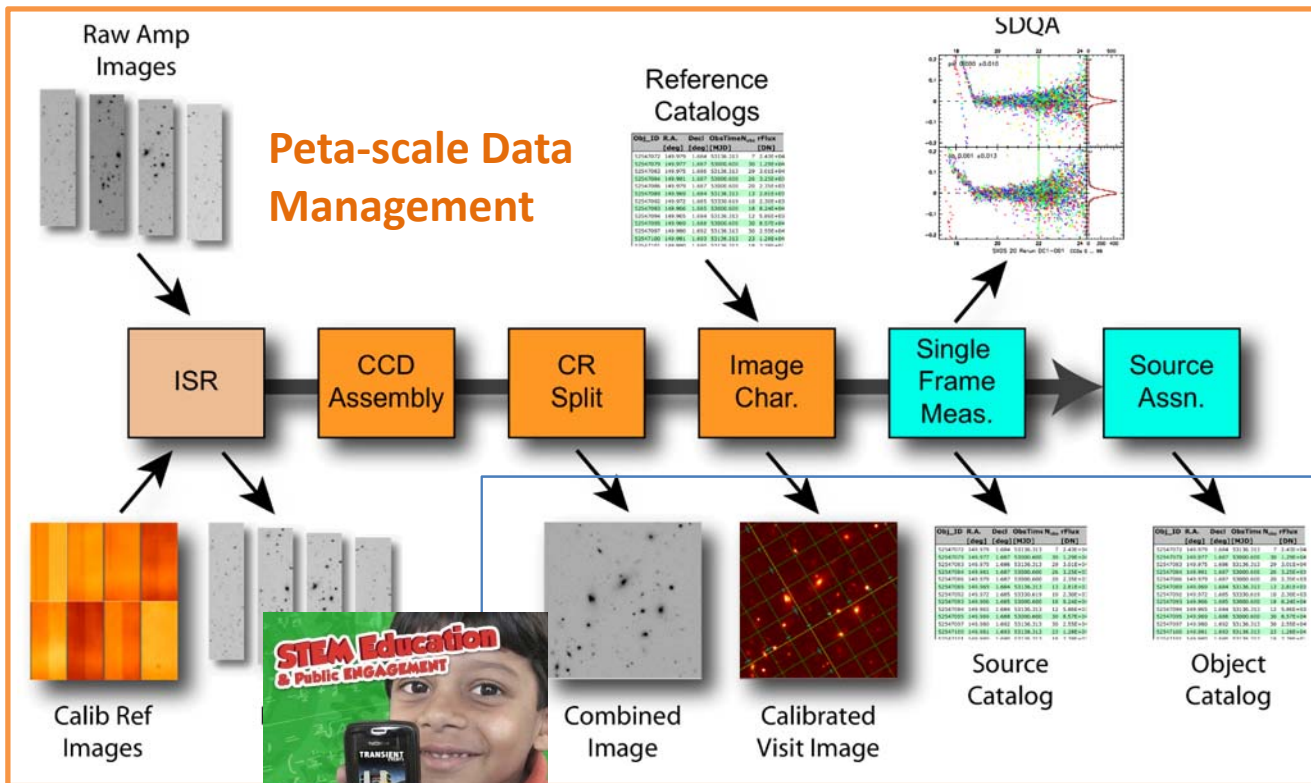
To build an observing facility, conduct 10-year survey, process, archive, and serve images and data products



8.4m Telescope



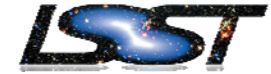
3.2Gpix Camera



Science and Public user Interfaces



Data Products



- 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 observations (“sources”), and ~30 trillion measurements (“forced sources”), produced annually, accessible through online databases.
- Deep co-added images.

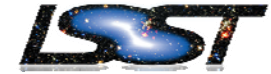
Prompt

Data
Releases

The production of data products will be transparent: All software is developed open-source and will be available to the community.



LSST Algorithm and Pipelines Progressing



Simulated image based on three filters
From just one of 189 CCDs

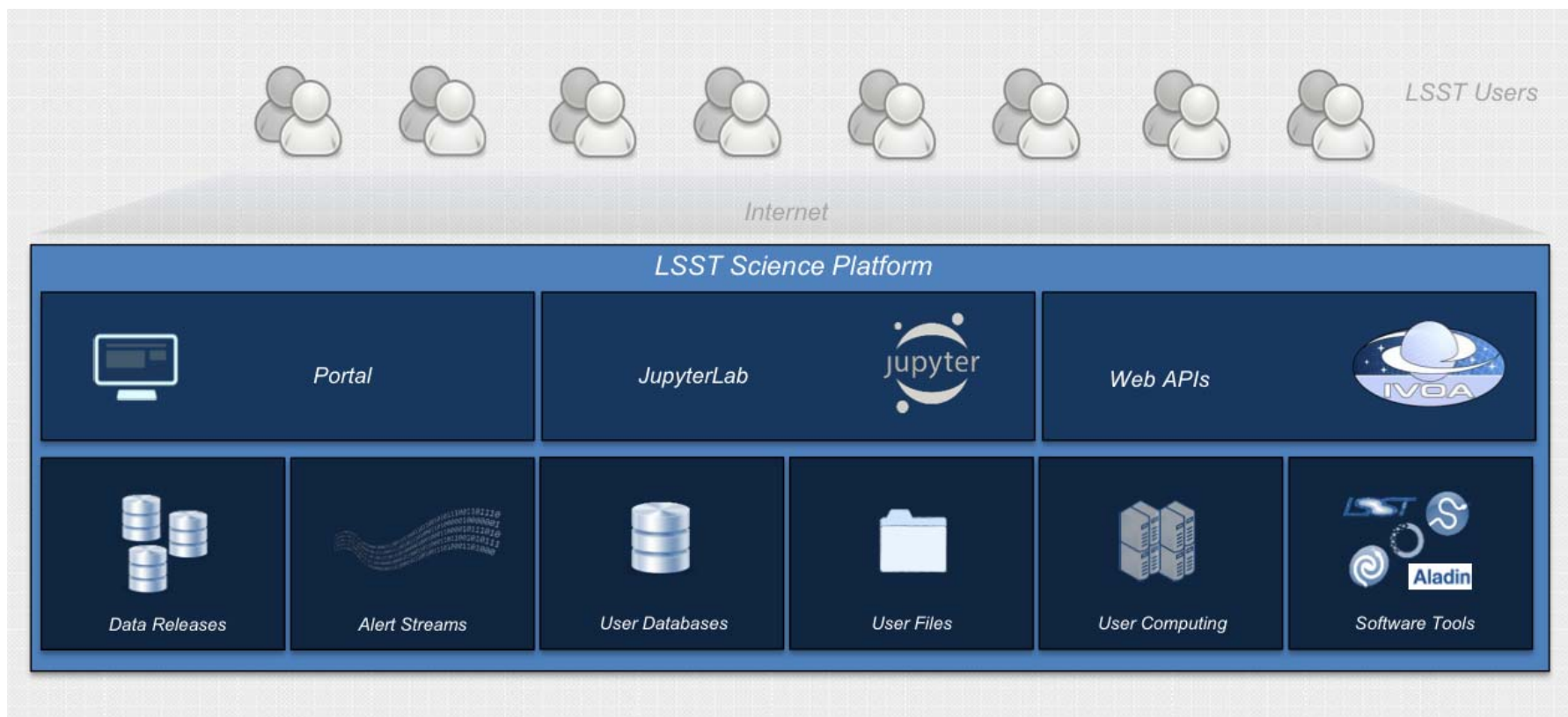
Processed through the
LSST Science Pipelines

<https://pipelines.lsst.io/>

The Pipelines are already in use with other facilities, e.g. Hyper Suprime-Cam.

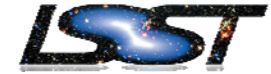


The LSST Science Platform: Portal, JupyterLab, WebAPIs





Science Platform Vision to Early Reality



Vision LSE-319 Design LDM-542 Test DMTR-51

The screenshot shows a Jupyter Notebook with two cells. The first cell contains Python code for processing point data and plotting a histogram of PSF sizes. The second cell contains code for processing shape data and plotting a scatter plot of pixel positions.

```

In [17]: sizes = numpy.asarray(sizes)
         hist = plt.hist(sizes*pixel_to_arcsec, bins=100)
         plt.xlabel("PSF size in arcseconds")

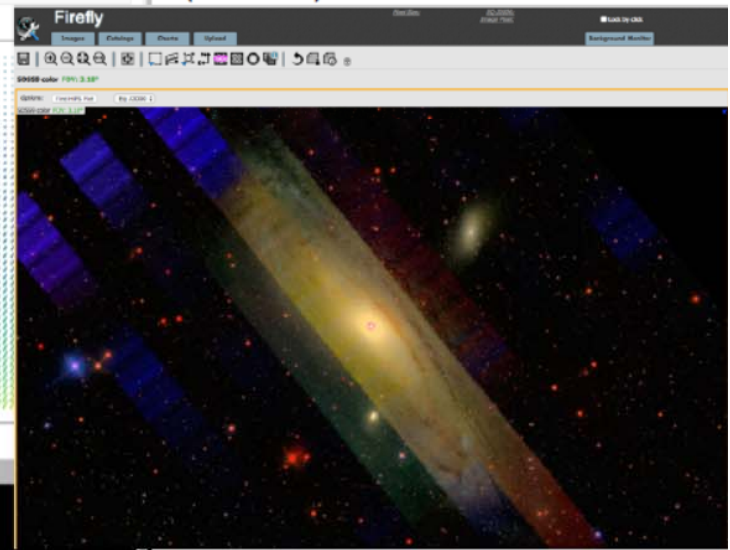
Out[17]: <matplotlib.text.Text at 0x7f7b7804a8>

In [18]: a_vals = numpy.asarray([e[0] for e in shapes])
         b_vals = numpy.asarray([e[1] for e in shapes])
         t_vals = numpy.asarray([e[2] for e in shapes])
         sizes = numpy.asarray(sizes)
         e_vals = a_vals/b_vals
         sizes -- numpy.min(sizes)
         u = numpy.cos(t_vals)*sizes
         v = numpy.sin(t_vals)*sizes
         ax = plt.axes([0,0,1,1], sharex=True, sharey=True)
         ax = plt.gca()
         ax.scatter(x=u, y=v, c=e_vals, headwidth=0, headlength=0, headaxislength=0)
         ax.set_xlabel("Semi-major axis/Semi-minor axis")
         ax.set_ylabel("x pixel position")
         plt.ylabel("y pixel position")

Out[18]: <matplotlib.text.Text at 0x7f742334be0>

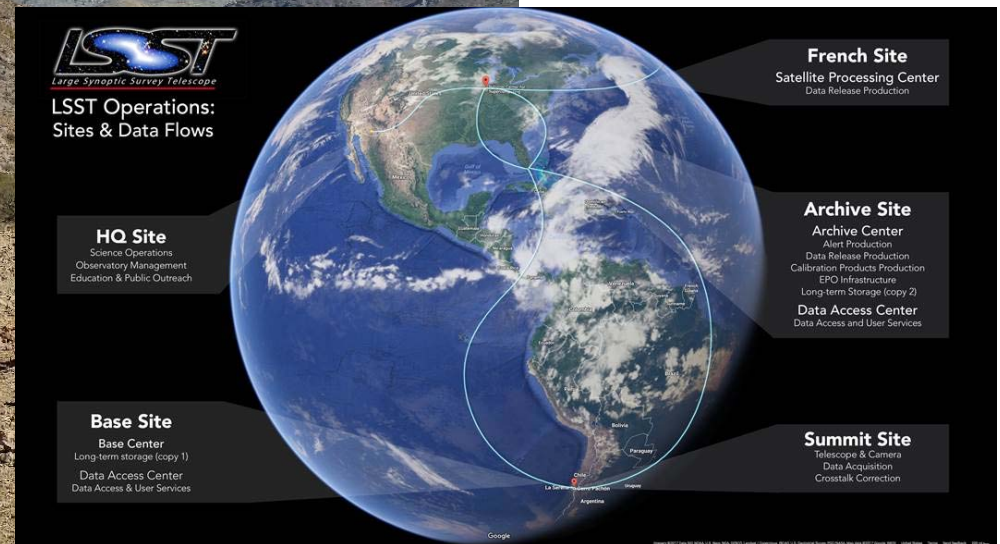
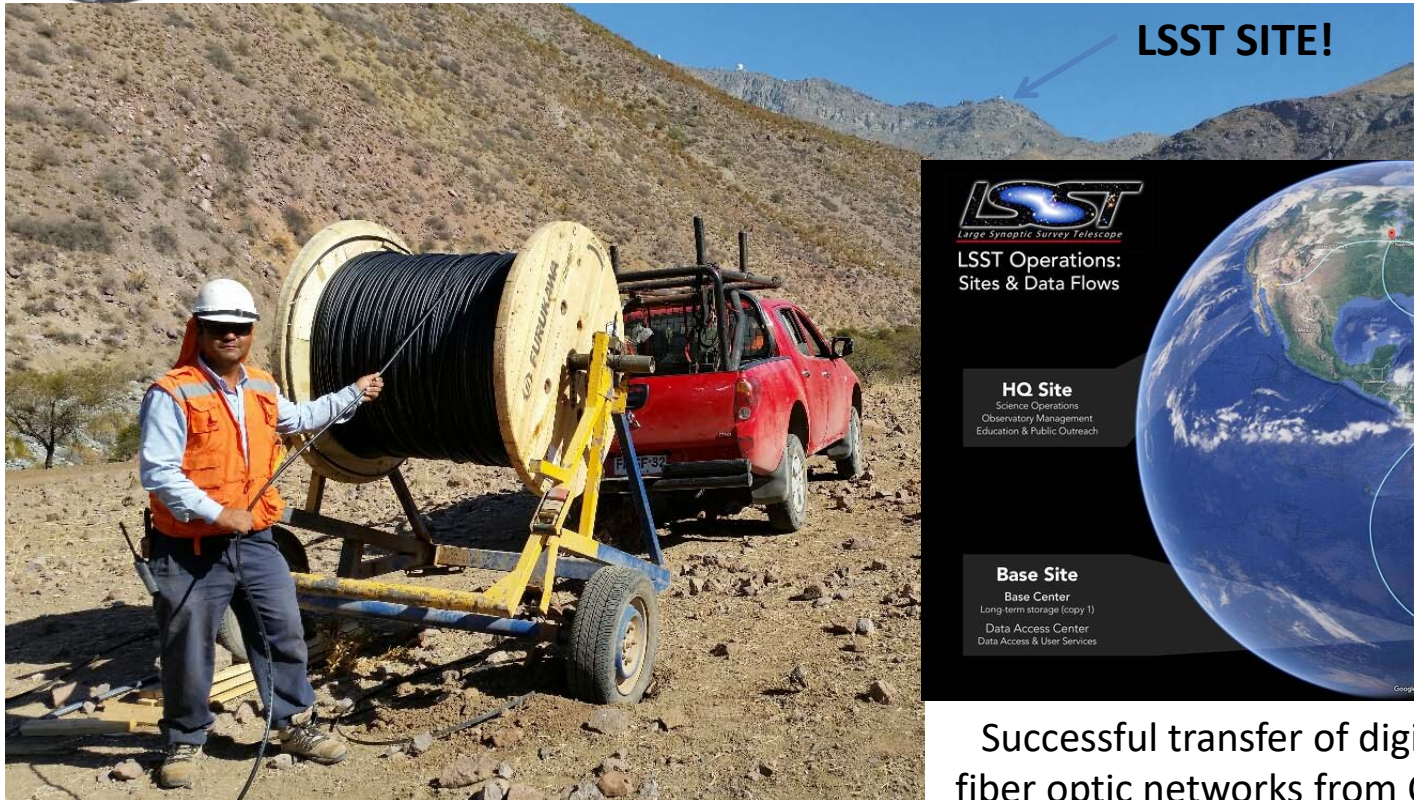
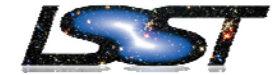
```

Portal/Browser
Notebooks
Web API
(Batch)





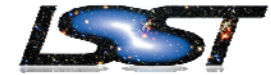
New optical fiber to the summit completes path



Successful transfer of digital data over LSST/AURA fiber optic networks from Cerro Pachón to La Serena and on NCSA.



The LSST Education and Public Outreach System



The mission of LSST EPO is to provide non-specialists access to a subset of LSST data through accessible and engaging online experiences so anyone can explore the Universe and be part of the discovery process.

Audiences:

1. Formal educators teaching astronomy content at the advanced middle school, high school, or college level
2. Citizen science principal investigators (scientists using LSST data)
3. Content developers at informal science centers / planetariums
4. Science-interested teens and adults





Six- filter mixing tool



Color The Universe

Learn how to make astronomy images.

U Blue ▾

G Blue ▾

R Green ▾

I Orange ▾

Z Red ▾

Y Red ▾

Reset

Print

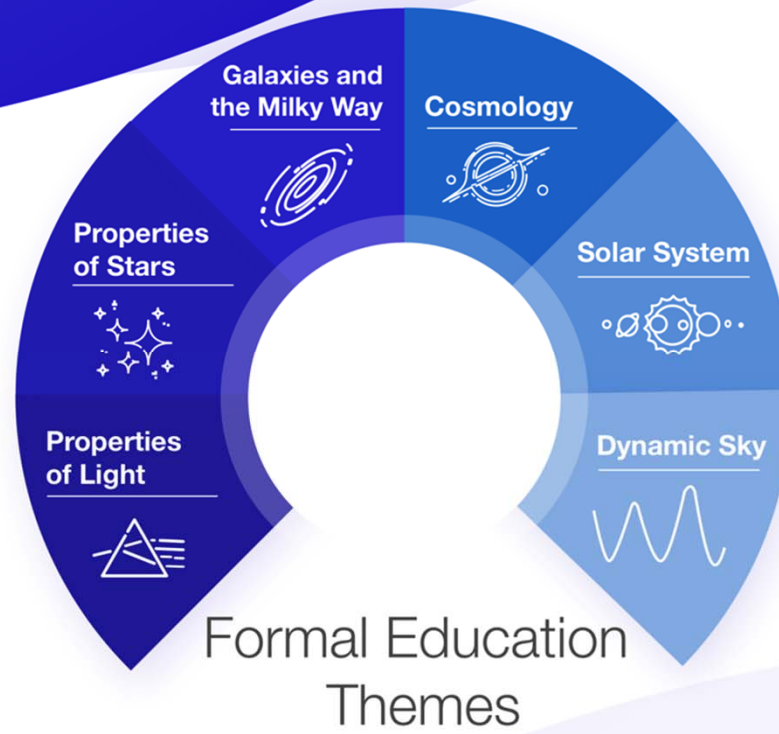


M33

<https://lsst-epo.github.io/properties-of-light/>



Science themes





Online Notebooks



- Accessible through a website
- No special software required
- No need to download data
- Embedded tools for data interaction & analysis
- Customizable
- Class management tools, teacher guide and assessment materials available for educators

Python 3

Introduction and Background

Today you will be using a data visualization tool called the **H-R Diagram**, first developed more than a century ago by **Ejnar Hertzsprung** from Denmark, and **Henry Norris Russell**, an American. The H-R Diagram will enable you to create your own "window" to the stars and explore what it can reveal about star properties such as size, temperature, and energy output.

In order to accurately compare stars to each other and measure properties such as their energy outputs, it is important to account for the fact that two stars of the same brightness will look very different if one is farther away from Earth than the other. One way to address this issue is to collect data from a group of stars in a **star cluster**, in which all the stars are the same distance away. Today you will collect and analyze data for the stars in one cluster, which will allow you to determine the variation that exists in stellar properties.

In this investigation, the term **luminosity** refers to the total energy output from a star per unit of time. Luminosity is typically reported as a ratio of the star's energy output compared to the energy emitted by the Sun. For example, a star with a **solar luminosity** of "10" emits ten times more energy than the Sun.

Procedure and Data

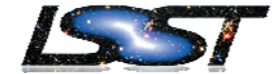
First call up the information and data for your star cluster. Type in the name of your cluster and press Enter:

Type in the name of your cluster and press Enter/Return: Berkeley 20

FOV: 25.16°



EPO is Prototyping and Evaluating



Alerts
STATUS ACTIVE

- Alerts Issued Last Night: 10 million
- Total Alerts Collected: 5,425
- Next Image Catalog Release: 306 days

RETROGRADE	SUPERNOVAE	LEADING STARS	TRANSNEPTUNIAN OBJECTS
1154	2200	32	10
Total to Date: 662,766	Total to Date: 662,766	Total to Date: 662,766	Total to Date: 662,766

Welcome to the Future of Astronomy

The Large Synoptic Survey Telescope (LSST) is a new astronomical "telescope" based in Chile. Every three nights, it images the entire southern night sky and will continue to do this for ten years. LSST is currently observing millions of objects per night, creating one of the largest data sets ever produced. It will track how objects change over time — from exploding stars to asteroids orbiting near earth. By rapidly photographing the night sky over this time, LSST is helping to answer questions ranging from the formation of our Solar System to the fundamental matter and energy components of the Universe.

What's New

- FINISHED** Hello!
- DARK MATTER HALOS** Observing Dark Worlds
- SPACE WALKS** Spot Grav. Lenses

Introduction and Background

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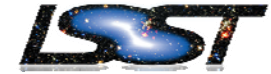
Procedure and Data

First call up the information and data for your star cluster. Type in the name of your cluster and press Enter:

Type in the name of your cluster and press Enter(Return): Berkeley 20



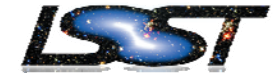
LSST Continues Focus on Safety



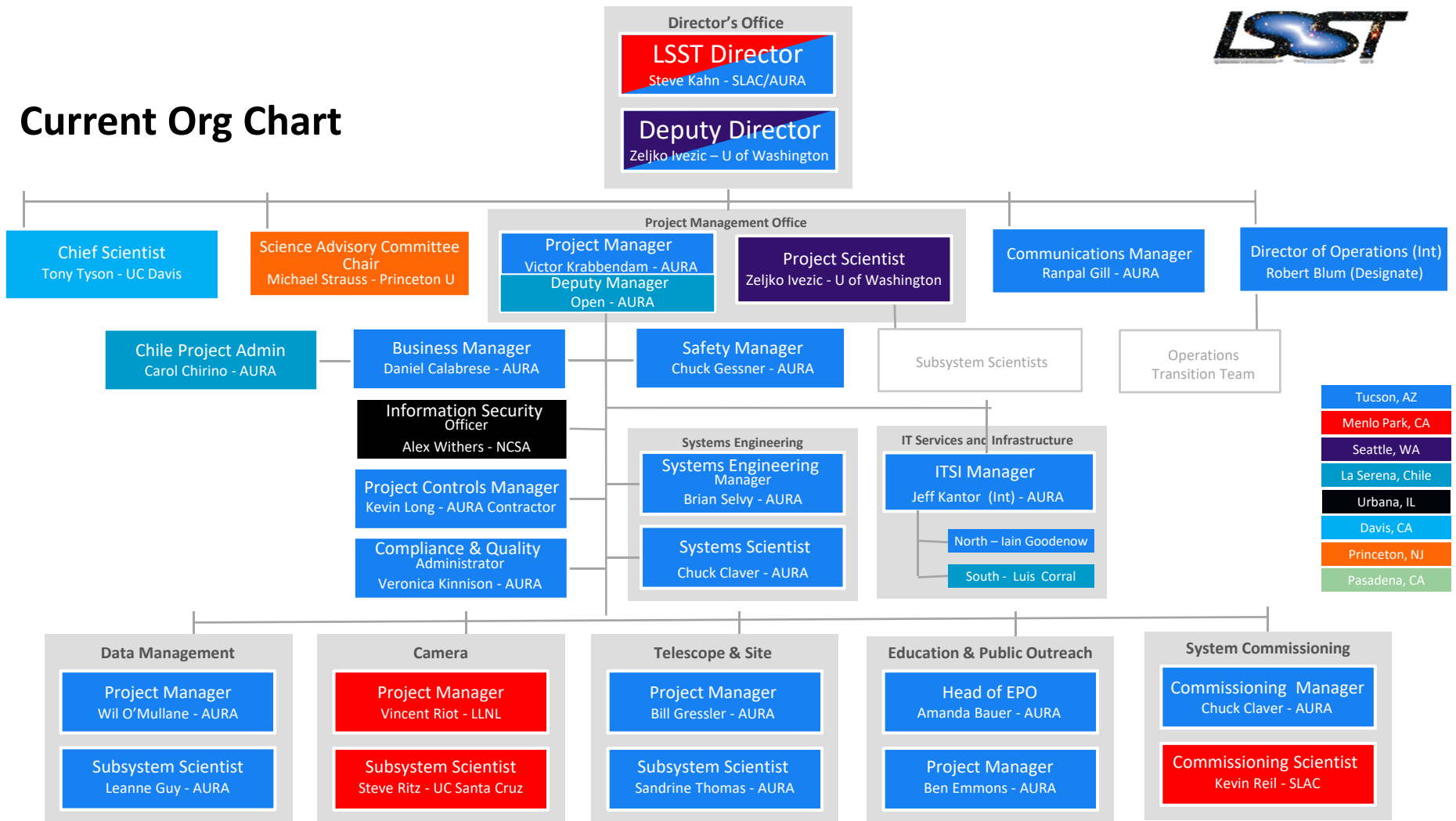
- Detailed tracking continues:
 - 0.37 injury rate (2016 US avg =2.9)
 - Rate = Incidents / 100FTE
 - Based on estimated 2.7 million hours
- Supporting 2 (3) construction sites
- Integrations activity assessments
 - SLAC, M1M3, TMA
- Culture - Attitude - Cooperation

SLAC - Camera Team	0
AURA - T&S, DM, and PO	.41
Summit Contractors	.46
<u>Base Facility Contractors</u>	<u>.41</u>
Total of these groups	.37





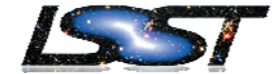
Current Org Chart



- Tucson, AZ
- Menlo Park, CA
- Seattle, WA
- La Serena, Chile
- Urbana, IL
- Davis, CA
- Princeton, NJ
- Pasadena, CA



EVMS Executive Summary – July 2018 Data

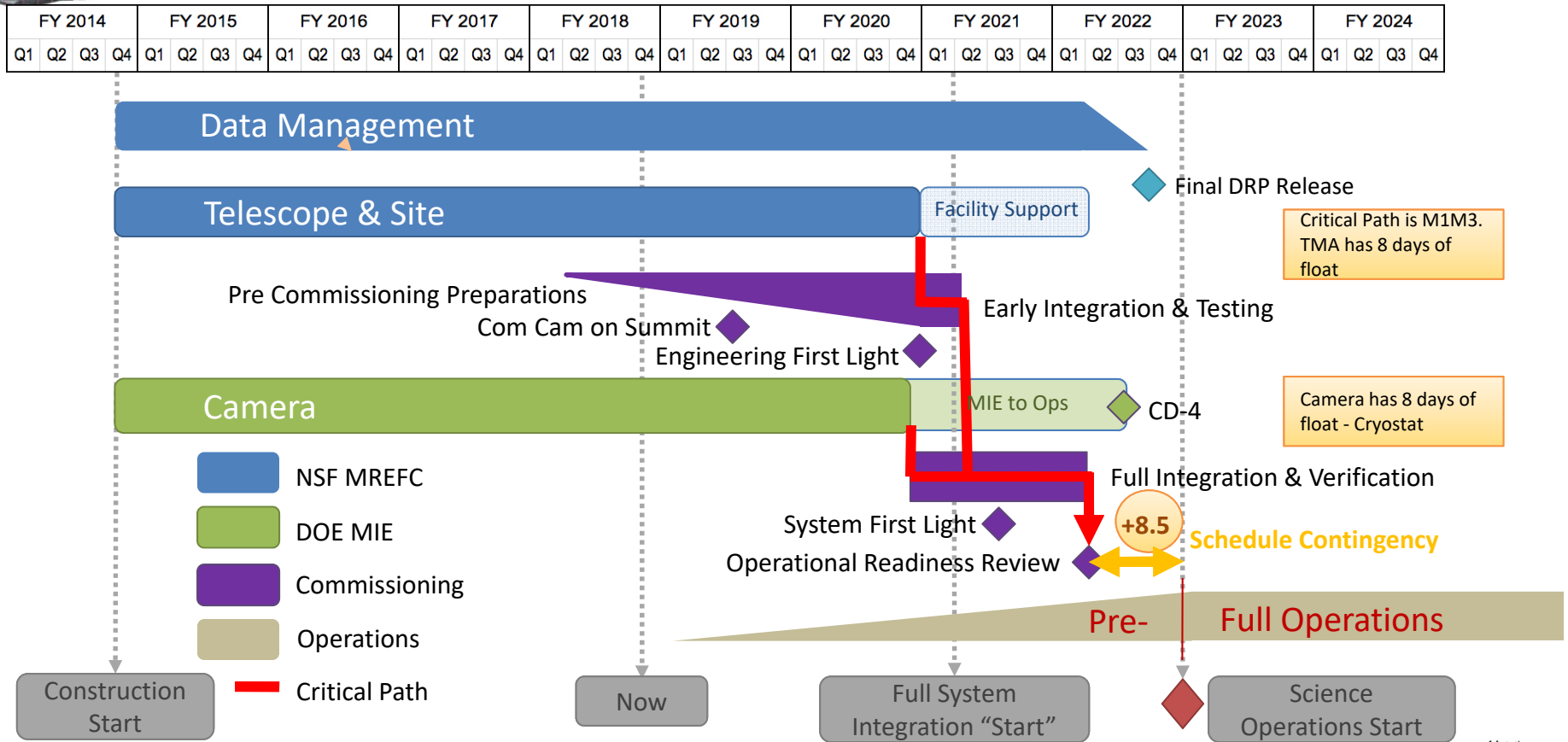
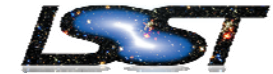


	MREFC - NSF	LSSTCam – DOE
% Complete (July 2018)	59	85
SPI	0.97	0.97
CPI	0.98	0.97
Contingency	\$37.4 M	\$6.6M
Contingency % Remaining Work	20	28

- Level 2 completion
- DM 44%
 - Camera 81%
 - T&S 76%
 - EPO 29%
 - SE / Commissioning 24%

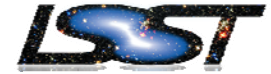


LSST Project Schedule – 8.5 Months Contingency



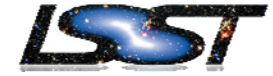


Overview Conclusion



- Technical progress is excellent.
- Team is extremely busy finishing hardware, detail planning integration, coordinating Verification and Validation.
- Project status by the numbers is good – Contingencies remain but are tight.
- Challenges and risks remain but LSST is currently on track for successful completion.

Made possible by an incredible team!



LSST Project and
Community
Workshop –
Tucson 2018



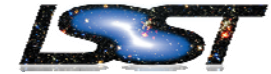
**On schedule for First
Light in 2021 and start of
10-year Survey in 2022**



Photo: Gianluca



Thank You.



LSST Week in Brazil: 24 – 28 September

Wil O’Mullane – Data Management Manager

Tuesday – 25 September 1:30 PM

Ranpal Gil – Senior Manager / Communications

Wednesday - 27 September 1:00 PM

Amanda Bauer – Head of Education and Public Outreach

Wednesday – 27 September 1:45 PM



www.lsst.org
LSST Template 11/17



This material is based upon work supported in part by the National Science Foundation through Cooperative Support Agreement (CSA) Award No. AST-1227061 under Governing Cooperative Agreement 1258333 managed by the Association of Universities for Research in Astronomy (AURA), and the Department of Energy under Contract No. DE-AC02-76SF00515 with the SLAC National Accelerator Laboratory. Additional LSST funding comes from private donations, grants to universities, and in-kind support from LSSTC Institutional Members.

Webinars



20/09 - 02:00 pm BRT

Victor Krabbendam (LSST)

LSST Project Status: The System is becoming Real

Abstract Presentation Video



25/09 - 01:30 pm BRT

William O'Mullane (LSST)

LSST Data Management Overview and Status

Abstract Presentation Video



26/09 - 01:45 pm BRT

Amanda Bauer (LSST)

LSST Education and Public Outreach (EPO)

Abstract Presentation Video



26/09 - 01:00 pm BRT

Ranpal Gill (LSST)

LSST Communications Office - A small but productive team

Abstract Presentation Video