



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Office of High Energy Physics (HEP) Cosmic Frontier

National Academy of Sciences

Committee on Astronomy and Astrophysics meeting

26 November 2019

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Program Manager, HEP Cosmic Frontier

Astro2020 – Statement of Task

NASA, NSF and DOE worked together to deliver a statement of task (SOT) to the National Academy of Sciences for Astro2020 (https://sites.nationalacademies.org/DEPS/Astro2020/DEPS_192912)

- Identify the most compelling science challenges and frontiers in astronomy and astrophysics, which shall motivate the committee's strategy for the future
- Develop a comprehensive research strategy to advance the frontiers of astronomy and astrophysics for the period 2022-2032...
 - ...For each recommended activity the committee will lay out the principal science objectives and activity capabilities, including assumed or recommended activity lifetime.
- Utilize and recommend decision rules...



HEP & Astro2020 Considerations

→ Guidance from Astro2020 will inform HEP on

- Compelling, high impact science directions and research strategies
- Opportunities that HEP can consider for contributions, including*:
 - select, high impact experiments with discovery potential
 - that address HEP science goals
 - where DOE HEP researchers and investments can play a significant role in & make unique, significant & necessary contributions
- Potential partnerships with NASA, NSF & international collaborators

HEP Interactions with Astro2020:

- Jan 2019 – met with Fiona and Rob at AAS
- Apr 2019 – met with Fiona and Rob at NAS
- Jul 2019 – Presented to Survey Committee 1st meeting
- Oct 2019 – Presented to Enabling Foundations for Research panel
- Nov 2019 – Presented to Radio, Millimeter, Submillimeter panel
- Nov 2019 – Presented to State of the Profession panel

** These are the 2009 HEPAP/PASAG report criteria*



HEP & Astro2020 Guidance

Asking for Guidance on:

- *Science justification and directions*
- *Technical specifications to achieve science*
- *Priorities across Astro2020 areas*
- *Why HEP is needed for participation*

Not asking for detailed:

- *Project designs*
- *Prescriptions for how the agencies should split scope, funds.*

Astro2020 recommendations – *Depending on the opportunity*

- *Larger or longer term efforts will need to feed into the next P5 process to consider priority within larger HEP program.*
- *Smaller or near term efforts may be addressed without going to P5.*

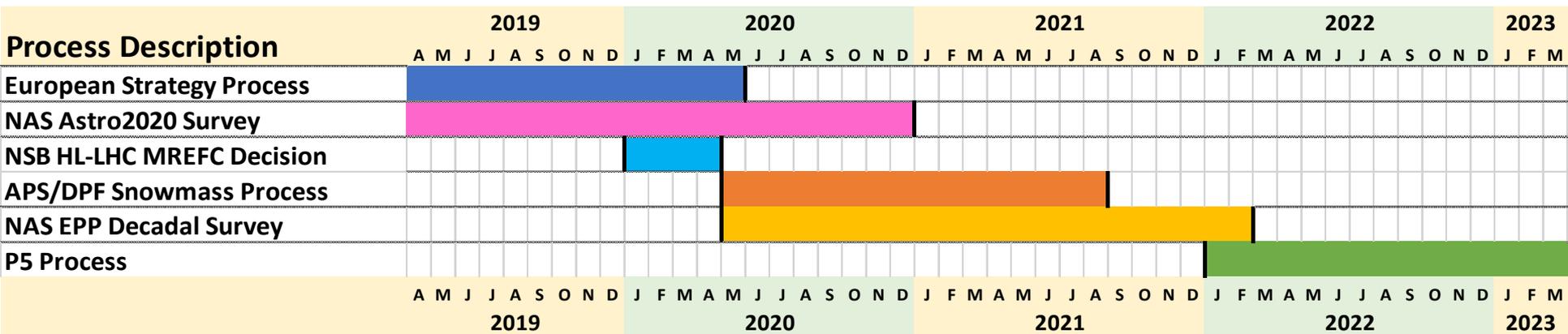
→ When making recommendations, consider the FULL needs, i.e.

Research/Scientist support, Project Design and Fabrication, Experimental Operations, Computing resources, Technology development and readiness, Data Analysis, etc.



Strategic Planning Timeline – Next Phase

- ▶ **The timeline of processes that impact the next strategic plan:**
 - ▶ 2018-20: **NAS Astronomy and Astrophysics Decadal Survey for 2020**
 - ▶ 2019: Start of European Strategy for Particle Physics process
 - ▶ 2019/20: Anticipated Japanese decision on ILC
 - ▶ 2020: Release of updated European Strategy for Particle Physics
 - ▶ 2020: Earliest opportunity for National Science Board to approve obligating HL-LHC MREFC
- ▶ **From a DOE perspective, the earliest that new APS/DPF Snowmass, NAS Elementary Particle Physics Decadal Survey, and P5 strategic plan processes could begin is 2020** (Snowmass community workshops are April 2020 – July 2021)
 - ▶ **Relative timing of P5 and NAS EPP Decadal Survey to be determined**
 - ▶ **Enables receiving next P5 recommendations by March 2023, in time to inform FY 2025 budget formulation**



Dark Energy – Current Program

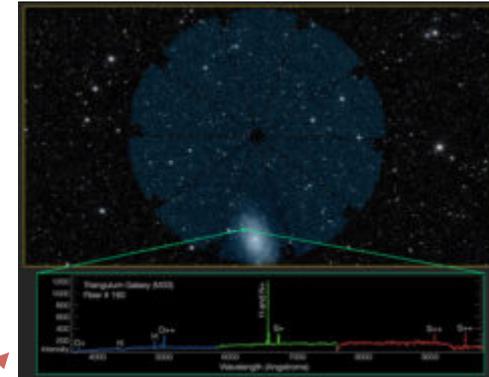
Precision measurements to differentiate between cosmological constant or new fields, or modification to General Relativity

Staged, complementary suite of imaging and spectroscopic surveys to determine its nature (in partnership with NSF-AST)

Stage 3 - Completed Data-Taking:

eBOSS (spectroscopic) started in 2015, ended Feb 2019

DES (imaging) started 5-year survey in late FY13, ended Jan 2019



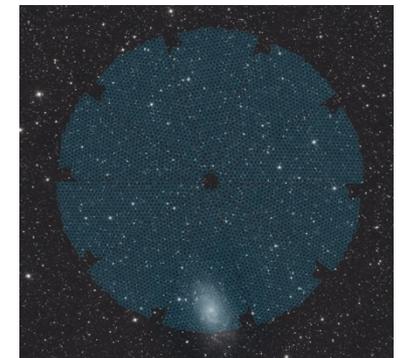
Stage 4 - Projects in Fabrication phase:

Large Synoptic Survey Telescope (LSST)

- DOE responsible for camera, then commissioning and observatory operations joint with NSF

Dark Energy Spectroscopic Instrument (DESI)

FIRST LIGHT Oct. 2019!



Cosmic Frontier – Planning Relevant for Astro2020

P5 science drivers: Cosmic Inflation, Neutrino Properties, New Physics

- ▶ **CMB-S4** is being proposed to Astro 2020 as a partnership of DOE-HEP, NSF-AST/PHY/OPP → **HEP is moving forward on CMB-S4 as recommended in our 2014 P5 strategic plan**
- ▶ **Dark Energy:**
Requires development in theory, simulations, joint data analyses, technologies for Stage 5, methods to increase redshift range, accuracy and statistics.
- ▶ **Dark Matter Direct Detection** – excluded in SOT due to purview of HEP/ Particle Physics community; fully informed by HEPAP/P5

HEP Cosmic Frontier is dynamic → the community & HEP are always looking for high scientific impact opportunities that align with our science goals & make use of HEP community's capabilities.



CMB-S4 Project and Collaboration Planning Status – 2019,2020

Formed Integrated Project Office (IPO) in FY2019 (Jim Yeck interim PM)

- Refine cost, plan for detectors, concept & layout of scope
- Detector fabrication & readout issues at the forefront of R&D/planning - No new technology, but scale-up needed.

DOE → approved Critical Decision 0 “Mission Need” on July 25, 2019; now being planned as a project

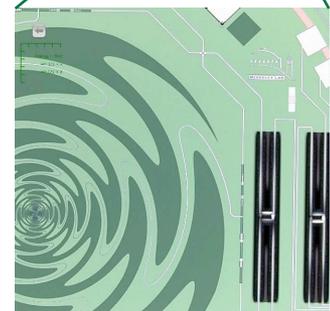
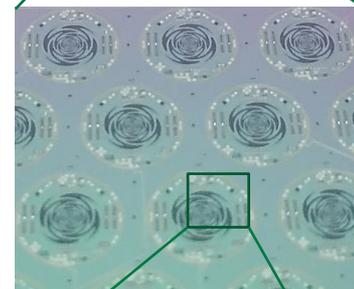
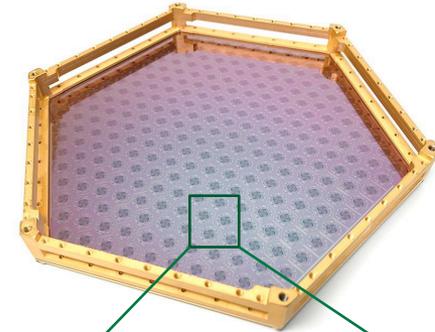
- HEP provided FY19 funds for R&D and concept planning; working to provide FY20 funds; NSF MSRI award (Oct’19)

Project (IPO and Collaboration) efforts:

- ▶ July 2019 submission(s) to NAS Astro2020 decadal survey (done)
- ▶ Detector fabrication and readout Task Force, refine concept and planning (done, work in progress); August 2019 review
- ▶ Developing technically-driven plan to meet CD-1 and NSF PDR requirements on the same timeline (mid CY2021)
- ▶ Nov. 2019 independent review of project status
- ▶ RFI report to this committee (in progress)

Interagency (NSF-DOE) Joint Oversight Group (JOG)

- ▶ Bi-weekly ad hoc NSF/DOE meeting to share information, monitor, and review; Bi-monthly meeting with IPO to review status

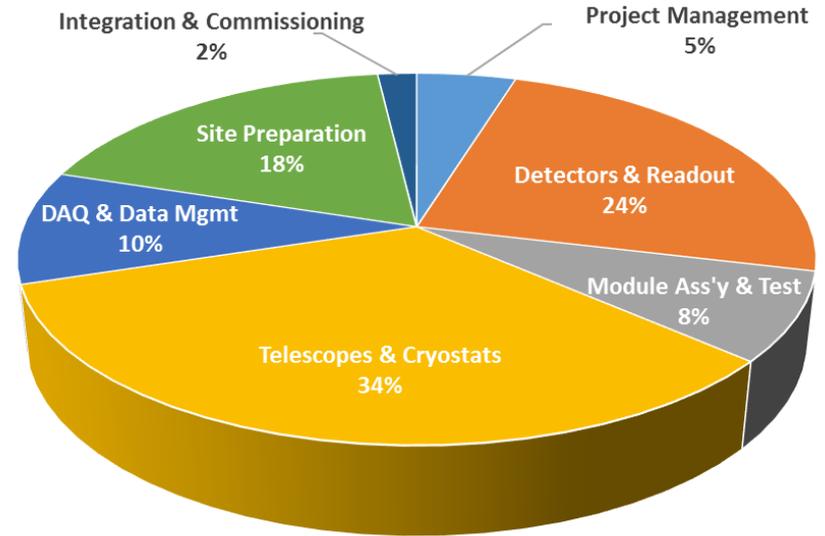


CMB-S4 Planning – Current Status

Current cost estimate

~\$590M w/35% contingency

Agencies & Project will work out scope distribution, leadership; depends on project needs and capabilities plus agency considerations



Schedule Drivers:

- Keep to P5 timeline; ready to start after Astro2020 report
- Maintain synchronization between NSF and DOE processes

Agency\FY	19	20	21	22	23	24	25	26	27
DOE	CD0		CD1/3a	CD2	CD3b			CD4/Ops	First Light
NSF	MSRI-1		PDR	FDR		MREFC Start			
Decadal Survey			Results						

Determining the Nature of Dark Energy – Next Generation

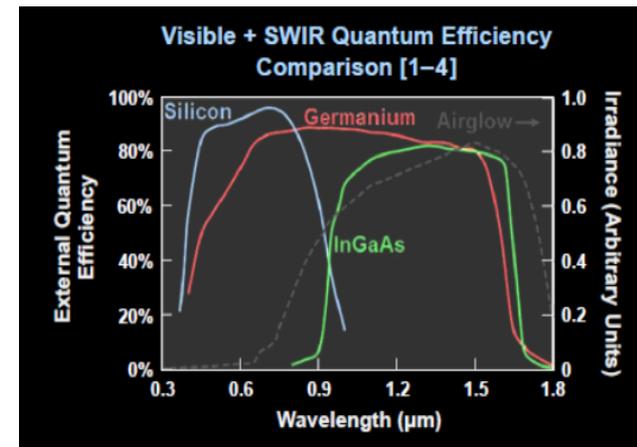
Power of a cosmic survey for precision measurements of cosmological parameters is limited by Redshift accuracy, Redshift range, Statistics

To fully exploit current program of ground- and space-based experiment will require advances in theory, data analysis and computing

- Cross-cutting theory and simulations efforts
- Joint modeling and analysis of imaging, spectroscopic, CMB and other data
- Exascale Cosmological Simulations - Expanding the nonlinear structure frontier, pushing to smaller scales

Community efforts:

- Cosmic Visions Dark Energy group investigating ways to optimize science in DESI/LSST era
 - White paper on small “enhance” efforts in Jan 2018 [arXiv:1802.07216](https://arxiv.org/abs/1802.07216)
- Technology development for Stage 5 galaxy surveys
 - Germanium CCD R&D
 - Fiber positioner designs to increase density
- Leading or participating in some concepts – white papers submitted to Astro2020 (e.g. CMB-S4, Megamapper, SpecTel)



Dark Energy Spectroscopic Instrument (DESI) - Status

DESI is an “HEP experiment” starting commissioning phase. Mounted and operating on NSF’s Mayall telescope at Kitt Peak, which HEP is “leasing”

- Science: Dark Energy using Baryon Acoustic Oscillation etc.
- LBNL is the lead lab

MIE Project: instrumentation & data management system, led by LBNL
- 8 sq deg FOV, 10 3-channel spectrographs w/5000 robotic positioners

First Light on October 22!

Status:

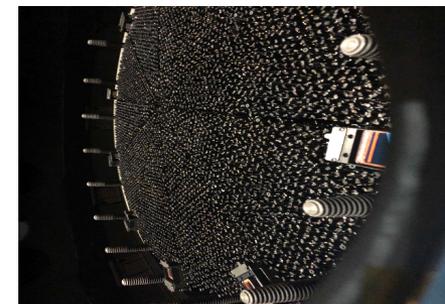
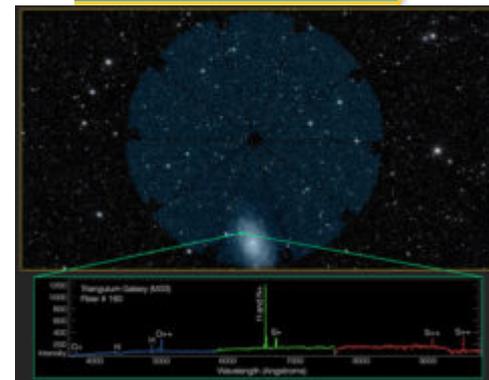
- All MIE project funding provided by FY19
- As of Oct. 2019: 93% complete; All 10 petals with 5000 fiber-fed robotic positioners in the barrel; 9 of 10 spectrographs installed.
- Commissioning started **Oct. 22, 2019**
- All Deliverables complete March 2020 (CD-4 9/21)
- All imaging surveys for target selection completed (16,000 sq deg)

Operations: 5 year survey

- Planning and pre-ops activities are ongoing
- HEP supporting full Mayall operations starting FY20
- Full science operations starts July 2020

Data Releases (DR):

- ▶ DESI commissioning using DR-8 Legacy Targeting Survey (July 2019)
- ▶ DESI survey will use DR-9 (December 2019)



DESI Career Development

70+ institutions, 500 scientists, including 140 graduate students!

- US Collaboration is: LBNL (lead), with FNAL, SLAC, ANL, BNL, LLNL plus 21 US Universities



Claire Poppett (Lead Observer), Stéphanie Juneau (NOAO) & Suk Sien Tie (OSU)

- ▶ **Robust university-laboratory partnership** with numerous important instrumentation subsystems developed and built at universities. Key examples: fiber positioners built at UMichigan, instrument control system, commissioning camera, & sky monitor built at Ohio State U, fiber view camera built at Yale, and petal-bodies machined at Boston U.
- ▶ **Code-of-conduct** policy, Meeting code-of-conduct policy
- ▶ **Diversity** – DESI is 24% women scientists. LBL technical staff on DESI is 15 men:15 women; Fraction is higher at early career
- ▶ Diversity is improved by promoting **Early Career Scientists**
 - ▶ Subsidized travel to DESI meetings

Large Synoptic Survey Telescope (LSST)

DOE-HEP & NSF-AST partnership, currently in its Construction phase.

→ **1 project, 2 agencies** w/international, private contributions

- **NSF is the lead Agency.**
- **SLAC** is the DOE lead lab & carries out responsibilities
 - Significant efforts by BNL, LLNL, universities

Construction Project: NSF/DOE MOU in 2012

New state of the art observatory facility on Cerro Pachon in Chile

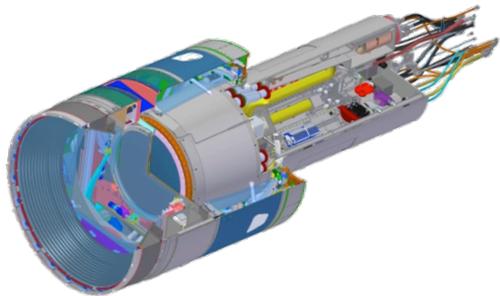
NSF: 8.4m wide-field Telescope & Site (T&S), Data Management (DM), EPO

DOE: 3.2 giga-pixel Camera

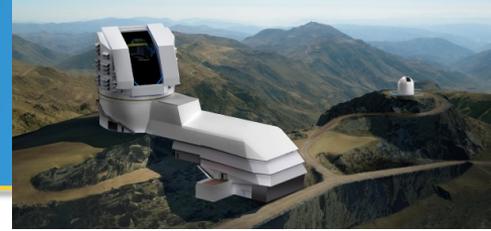


Camera: 96% complete as of Oct 2019

- All MIE funding provided by FY18, TPC \$168M
 - MIE completes when Camera is integrated and tested at SLAC; planned to complete April 2021, Critical Decision 4 (CD-4) milestone March 2022.
- Camera integration and commissioning with T&S and DM system in Chile is supported on HEP program funds; lined up with NSF's MREFC to complete at end of FY2022.



Large Synoptic Survey Telescope (LSST)



Facility Operations

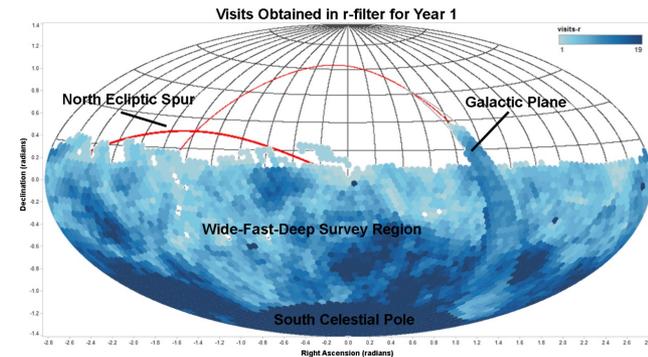
The LSST facility will conduct a 10-year deep, wide, fast, optical imaging survey of more than 37 billion objects

May 2019: DOE and NSF agree to provide ~ equal support for Operations. International in-kind contributions in exchange for data rights/access will be approved by the agencies.

- Pre-operations planning and activities have started
- Full science operations at start of FY2023.

Agency Oversight and Reviews:

- Weekly NSF/DOE Joint Oversight Group (JOG) meetings
- Joint reviews of Project and Facility Operations plans



Scientific Research - Both NSF and DOE will support community efforts

- DOE's research efforts are primarily in the study of Dark Energy, which is organized through Dark Energy Science Collaboration (DESC); planning activities are continuing





Construction Funding Partners and Managing Organizations



US\$ 473 M



MREFC
Project



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US\$ 168 M



MIE Project

Private, Corporate, and
Institutional Donors

US\$ 40 M was key to early development



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slide from Victor Krabbendam

LSST Dark Energy Science Collaboration (DESC)



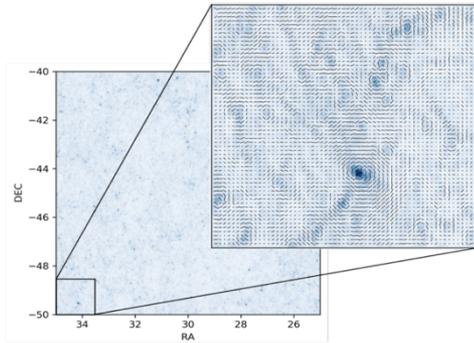
www.lsstdesc.org

- Set up to carry out planning, preparations and eventual data analysis to support HEP science goals for precision dark energy analyses
- Operations Plan review held May 2018; planning continues.

As of July 2019, the collaboration has 949 Members and 215 Full Members.

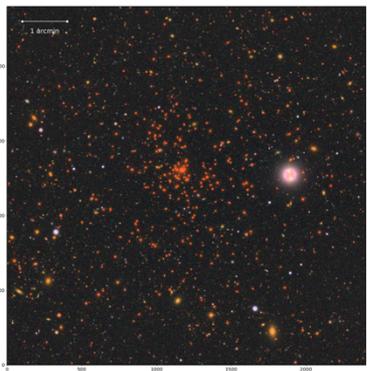
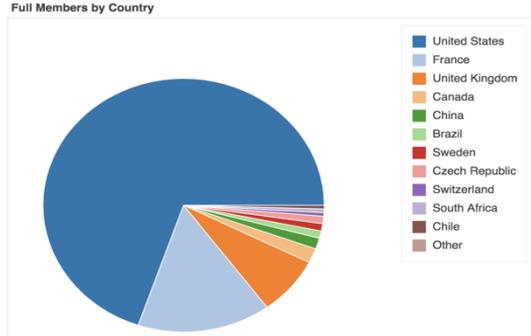
- *Full Members have committed a significant fraction of their research time to the DESC, and have voting rights.*

Updates since June 2019:



Public release of CosmoDC2, a state-of-the-art extragalactic catalog that can be used to test cosmological analysis methodology

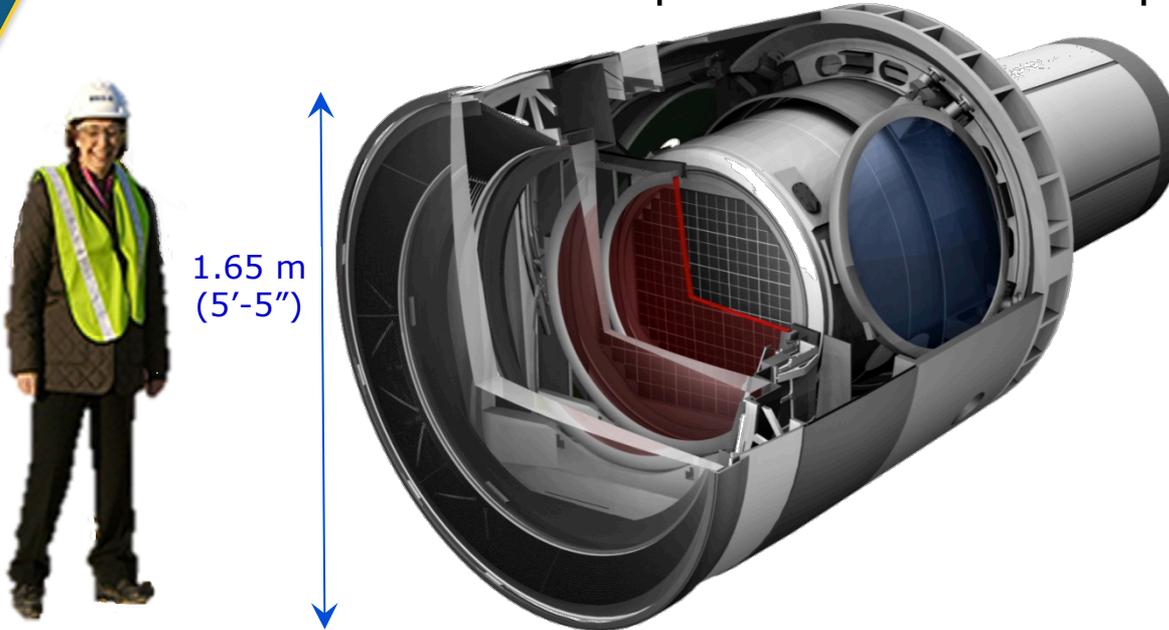
15 DESC papers published or submitted in 2019 so far. DESC is actively preparing for cosmological analysis with LSST!



DESC's image simulations may help LSST Operations practice serving LSST data to the broader science community. (Image credit: Dominique Boutigny)

LSST Camera – 96% Complete!

Enormous **Camera** to exploit the wide 9.6 sq deg field of view (FOV)



The 3.2 Gigapixel LSST Camera will be the largest electronic camera ever built for ground-based astronomy.

- The world's largest high-performance optical lens ever fabricated
- Six optical filters, five of which are resident in the camera on any given night.

3.2 GigaPixel Camera

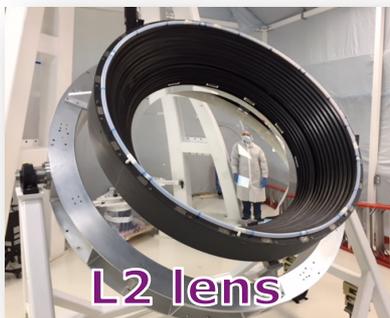
- 63 cm focal plane
- 2 second readout (fast!)
- 3060 kg
- 1.57 m front Lens
- 6 filters 0.3 – 1.1 μ



LSST Camera Project Status

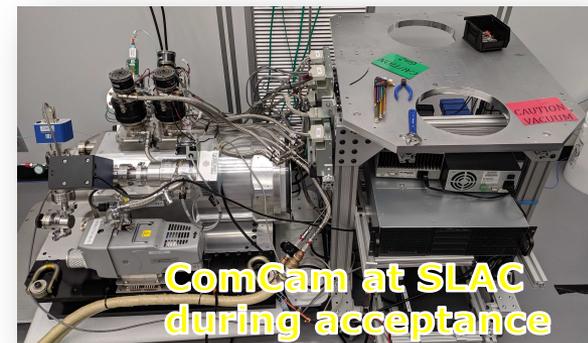
- All Sensors have been received and assembled in science rafts, which have been fully delivered from BNL.
- 9 science rafts and 4 corner rafts have been integrated into the cryostat; Cold electro-optical test completed 11/04/2019 with good results.
- 12 remaining rafts installation starts soon, to complete in Jan.

- L1, L2, L3 lens assemblies shipped to SLAC from LLNL/vendor on 8/15/19, 10/8/19
- Filter Changer (France) – on the way to SLAC
- Refrigeration system and vacuum system has been tested successfully



Camera commissioning effort started in Chile - auxiliary room and camera clean room

Commissioning Camera (ComCam) focal plane delivered to LSST Project



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	MREFC - NSF	LSSTCam – DOE
% Complete (Sept 2019)	75	96
SPI	0.99	0.98
CPI	0.98	0.97
Contingency (EAC)	\$11.5 M	\$2.0M
Contingency % Remaining Work (EAC)	25*	27

Summary

HEP Cosmic Frontier projects from Astro2010 and P5 are about to commence observations and deliver Stage 4 dark energy science – and much more astrophysics.

HEP looks forward to Astro2020 assessment of the most compelling science challenges, a comprehensive research strategy, and articulated decision rules with an eye to where DOE HEP researchers and investments can play a significant role in & make unique, significant & necessary contributions.

DESI is in commissioning, returning astrophysical spectra!

LSST camera project is 96% complete!

CMB-S4 has DOE CD-0 and a NSF MSRI-1. The NSF-DOE Joint Oversight Group meets biweekly. The collaboration is working hard toward DOE CD-1 and NSF PDR, ready to start after Astro2020.

