Snowmass2021 - Letter of Interest

The Rubin/LSST Dark Energy Science Collaboration: Operations during the LSST Survey

Thematic Areas: (check all that apply □/■)

□ (CF1) Dark Matter: Particle Like
□ (CF2) Dark Matter: Wavelike
■ (CF3) Dark Matter: Cosmic Probes
■ (CF4) Dark Energy and Cosmic Acceleration: The Modern Universe
□ (CF5) Dark Energy and Cosmic Acceleration: Cosmic Dawn and Before
■ (CF6) Dark Energy and Cosmic Acceleration: Complementarity of Probes and New Facilities
■ (CF7) Cosmic Probes of Fundamental Physics
■ (CompF1) Experimental Algorithm Parallelization
■ (CompF2) Theoretical Calculations and Simulation
■ (CompF5) End User Analysis

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Abstract:

The Vera C. Rubin Observatory is a joint DOE-NSF facility that is scheduled to begin its Legacy Survey of Space and Time (LSST) in FY2023. The LSST Dark Energy Science Collaboration (DESC) is the DOE-funded experimental collaboration focused on turning Rubin Observatory data into scientific measurements of dark energy and other fundamental physics. During the 10-year LSST, DESC Operations will need to adapt to evolving scientific priorities and to facilitate joint analyses with complementary facilities. Funding of operations for DESC, Rubin Observatory, and other experiments needs to be robust, stable, and flexible in order to achieve transformative measurements of fundamental physics in the next decade.

Background: The Dark Energy Science Collaboration (DESC)[1,2] will use data from the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST)[3,4] to perform transformative cosmological measurements of the fundamental physics of dark energy, dark matter, neutrinos, and inflation. Rubin Observatory is under construction and will provide data releases to those with LSST data rights starting in 2023. However, substantial algorithmic, simulation, analysis, and reprocessing software infrastructure must be developed to enable robust and timely measurements of fundamental physics using those data. That development work, supported by DOE HEP and international agencies, is the goal of DESC. DESC has $\sim$500 active members, of whom $\sim$70% have institutional affiliations in the USA.

Traditional HEP facilities are distinguished from the experiments they enable, e.g. ATLAS at the LHC, but construction and analysis are typically part of the same organizational scheme. While LSST shares this distinction between Rubin (facility) and DESC (experiment), its unusual organizational structure divides the Rubin facility from the science collaborations analyzing the data as separate entities. Given the need to design, implement, and validate complex data analysis pipelines before the flow of LSST data commences in 2023, DESC was designated an operating experiment by DOE HEP in 2016. As the Rubin Observatory shifts from construction to its own operations phase, this creates opportunities for and risks to the eventual scientific productivity of DESC, some of which are relevant for other HEP experiments.

DESC Operations: During the 10-year LSST survey, Rubin Observatory Operations will include maintaining the telescope and camera, taking data, and processing the huge volume of data into nightly and (semi-)annual data releases. DESC Operations (Ops) includes the pipeline design, implementation, and validation against simulations needed to be ready for these data releases as well as the actual data analysis and publication of scientific results.

The majority of DESC costs, both for operations and R&D at universities and labs, are for personnel. DESC estimates infrastructure needs totaling $\sim$60 FTE per year. A core set of tasks accounting for roughly 1/4 of that effort requires individuals with unusual technical skills who efforts can be directed via contracts with defined work packages. Supporting directable individuals with those skill sets enables us to better leverage the remaining contributed effort from across the collaboration. Roughly half of that highly skilled, directable workforce is provided through in-kind contributions from DOE national labs and international partners, but we have found DESC Ops funding invaluable for addressing our highest priorities for data pipeline construction. Significant unexpected fluctuations in recent DESC Ops budgets have illustrated the importance of stable funding when personnel costs are the bulk of the budget. The current funding level of DESC Ops is enabling the assembly of a broadly talented, directable team able to support DESC's highest-priority scientific preparations.

Recommendations for Snowmass 2021

Though the following recommendations refer to the specific structure of DESC Ops, most of them imply corresponding recommendations for CMB-S4, DESI, Euclid, and Roman, etc. – i.e., all HEP experiments or astronomical surveys with significant data analysis components to their operations.

- **DESC Ops must adapt to evolving science priorities.**
  - Our understanding of HEP science that can be done with the LSST will evolve over the coming decade, as a result of Snowmass 2021 and ongoing discoveries. This may include additional probes of dark energy, e.g., standard sirens, and additional systematics that affect the planned probes.
  - There is important science that complements dark energy that DESC should prepare for, including cosmological probes of dark matter, neutrino masses, general relativity, and non-gaussianity

from the epoch of inflation (see the Walter et al. LOI on this topic). Much of this science has already been identified as Cosmic Frontiers priorities by P5.

- To maximize the scientific return for dark energy and cosmology with LSST, **DESC Ops will need to facilitate joint analyses with complementary facilities (DESI, Euclid, Roman, CMB-S4, etc.) and other LSST science collaborations.**

  - Preparing for these joint analyses requires development of joint pipelines and simulations, which requires additional resources.[5] Survey-specific information critical to the overall structure of joint analysis pipelines could be incorporated by developing them via inter-collaboration agreements between DESC and other experiments.
  - Joint simulations can be built on the well-developed DESC simulations infrastructure, as has been demonstrated with Roman+LSST imaging simulations.[5]
  - Joint processing of data from multiple facilities requires an even larger investment, with potentially greater rewards (as described in the Rhodes et al. LOI on this topic).

- To maximize the scientific return, **DESC Ops needs consistent, long-term support.**

  - Long-term maintenance is needed to guarantee research output from pipelines throughout the life-span of LSST. Pipelines designed today may have software or data formats that will not be supported in the future, and the format of LSST data releases will evolve with time.
  - Such support is a prerequisite for resiliency to surprises that demand redesign or re-implementation of pipelines. During survey operations, DESC will need to employ new computing resources, algorithms, and physical models as part of our analysis pipelines.
  - Assembling and maintaining the necessary skilled workforce requires that DESC have the ability to offer multi-year contracts for fractional FTEs. Even the possibility of severe budget cuts in the subsequent 1–2 fiscal years can cripple the ability to sign contracts with the personnel needed to develop, validate, operate, and refine the cosmology pipelines needed during the LSST survey.
  - As roughly half of the skilled personnel working on DESC Ops are provided in-kind by labs and universities, and the data complexity requires a mix of directable and contributed effort, stable R&D budgets are also essential.

- **DESC Ops and Rubin Ops both need stable funding structures.** The Rubin facility, like DESC, needs stable, consistent funding in order to produce high-quality data releases and to evolve data processing pipelines to incorporate lessons learned from early science. These are necessary steps for enabling DESC to realize the tremendous scientific potential of LSST for dark energy and cosmology.

- **Funding agencies should be aware of the emerging need for large astronomical surveys, including those pursuing HEP science, to receive dedicated operations funding.** DES,[6] DESI,[7] and DESC provide models for the level of coordination and stability needed to obtain robust and timely science results from huge datasets. For surveys that are performed on existing telescopes and instruments and therefore lack a construction component, DESC Ops may provide a useful model.

References

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