AURA's PERSPECTIVES ON
THE LARGE SYNOPTIC SURVEY TELESCOPE

1. Introduction – The LSST as a Powerful New Research Tool for the Entire Astronomical Community

AURA has long advocated for a wide field survey telescope that would provide a rich and varied data base for the entire astronomical community. Originally referred to as the Dark Matter Telescope, it was renamed the Large Synoptic Survey Telescope, or LSST, by the OIR panel of the 2000 Decadal Survey. NOAO's 1999 strategic plan proposed the construction of *two* wide-field telescopes "*in order to conduct deep imaging and spectroscopic surveys, to explore such issues as the evolution of galaxies and the nature of dark matter; to define the population of the solar system, including both asteroids and Kuiper Belt objects; and to study variable objects, including supernovae*." Interestingly, this was written shortly before the discovery of dark energy.

In partnership with the University of Arizona, AURA and NOAO strongly advocated for such a project to the OIR panel of the 2000 Decadal Survey. When the Panel's report was issued, they pointed out that the construction and operation of the LSST along with the handling of the data products "*present suitable opportunities for NOAO to provide a critical service to the community, in keeping with its new role*."

AURA, the Research Corporation, and the Universities of Arizona and Washington created a partnership (the LSST Corporation, or LSSTC) in March of 2003 to develop the LSST concept. Shortly afterwards NOAO, as an AURA operated center, was designated to represent AURA's interests on the LSSTC board. In early 2006 AURA submitted to the LSST Corporation a proposal to site the LSST on Cerro Pachon in Chile. In May 2006 an 11-member independent international review panel selected AURA's proposal to site the LSST on Cerro Pachon.

Many key positions in the LSST project, particularly those involved in telescope design and site development, are filled by engineers and scientists from the NOAO staff. The LSST project is working closely with AURA personnel in Chile on site testing and preparation and laying out plans for the handling of the vast and unprecedented amounts of data both locally, as it comes off the telescope, and globally for its transmission to data processing and storage centers in the United States.

The LSST has from its genesis been conceived as a community facility.

- LSST will have a strong impact across many fields of astronomy and astrophysics. As a consequence, the project has attracted broad community support with a growing list of 26 institutional partners in the United States including many of the leading universities, DOE laboratories, and private corporations including Google. LSSTC has received ~$50M in contributions from these member institutions as well as from private individuals. The project has also received financial support for Design and Development from the NSF and DOE.

- The database that it will produce and the associated object catalogs that will be generated from that database will be made available to the US scientific community and to the public at large *with no proprietary period*. *The science to be done with LSST's vast database will be carried out by the community*.

- The project has identified ten science collaborations to carry out detailed investigations within the broad science areas that LSST data will address. Already, ~250 astronomers have joined the collaborations. NOAO is serving as the clearing house for applications from the US astronomical community for membership on these science collaborations. Furthermore, as the host country for the telescope itself, Chilean astronomers will participate in all aspects of the project on an equal footing with their US colleagues. *This wide and growing participation on the science teams amply fulfils the expectation of the OIR panel of the 2000 Decadal Survey (quoted above) that participation in the LSST will present NOAO the opportunity to provide a critical service to the astronomical community.*

- Through the science collaborations the community has already submitted over 100 different proposals for carrying out breakthrough astronomy and astrophysics using data from the projected 10 year LSST survey.

There are several good examples of large-scale survey projects that although they were initiated by a "core-group" of astronomers, had as their goal the release of their data sets to the public to be "mined". The Sloan Digital Sky Survey is one striking example. As mentioned in the LSST Project's overview article (http://www.lsst.org/overview/overview_v1.0.pdf), the authors of more than 60% of the peer reviewed papers based on SDSS data (about 2080 papers and over 4000 distinct authors world wide as of 2008 October) have been by people from outside of the project. The Hubble, ACS, and Chandra deep field surveys are other good examples of the enormous community wide impact that data from large scale surveys have had.

Thus we see that AURA, via its initial advocacy for the LSST concept and its continuing active participation in the LSST project is acting on its mission statement "to promote excellence in astronomical research by providing access to state-of-the-art facilities".

In section 2 of this paper we present excerpts from the endorsements for the LSST from several NAS/NRC surveys of physics and astronomy. Section 3 provides an overview of the four key science drivers that motivate the project. In section 4 we summarize the educational and public outreach opportunities that the project presents. Most of the material in sections 3 and 4 are drawn directly from LSST documents and presentations that are publicly available on the World Wide Web. Finally, in section 5 we summarize the technical innovations that are driven by the challenges of building and operating LSST and ways in which these innovations are in turn driving further advances in related areas of technology.

2. LSST and NAS/NRC Studies and Surveys

The LSST Project has received top rankings by a diverse group of national panels and Federal agency advisory committees. In this section we highlight some of these. A more complete list may be found at http://www.lsst.org/About/reports.shtml.

2.1. The 2000 Decadal Survey in Astronomy and Astrophysics

The 2000 Decadal Survey in Astronomy and Astrophysics (DS) called for a 6.5-m class large-aperture synoptic survey telescope (LSST) that could survey the visible sky every week to a faintness level that would exceed all existing surveys. [LSST will have an effective aperture of 6.7-m.] The major goals that the DS noted encompassed Solar System studies such as a search for NEOs and Kuiper Belt objects, a study of the structure of the universe via observations of thousands of supernovae, and by measuring the distribution of dark matter via gravitational lensing studies. An LSST would also truly add the time dimension to astronomical observations thus opening up a new realm of discovery space. The DS drew particular attention to the fact that all of the data from the survey would be publicly available to astronomers and non-astronomers alike via a National Virtual Observatory.

The DS further noted that an LSST would complement NGST (now JWST) as well as a GSMT in their effort to determine the large scale properties of the universe as well as both of these telescopes and ALMA in their effort to study star formation and the planets. An apt analogy of this complementarity is the survey power of the 1.5-m Schmidt telescope on Palomar Mountain combined with the sensitivity of the 5-m Hale telescope.

The OIR panel of the DS ranked a LSST second on its list of major new ground based initiatives (the GSMT was ranked first). Overall, the 2000 Decadal Survey ranked LSST third on its list of major new ground based initiatives behind a GSMT and the EVLA.

2.2. Connecting Quarks with the Cosmos

In 2002 the Committee on the Physics of the Universe issued a report entitled Connecting Quarks with the Cosmos. In it they identified 11 questions that encapsulate the attempts of physicists and astronomers to understand the universe, one of which is understanding the nature of dark energy. The committee characterized this question as probably the most vexing of the eleven and went on to say that it is "the deepest mystery in physics and its resolution is likely to greatly advance our understanding of matter, space, and time."

The committee stated that in order to fully characterize and understand the nature of dark energy and its implications a new class of wide field, optical and near-IR survey telescopes would be required – one in space and one on the ground. One of their chief recommendations was to support the LSST project (recommended by the 2000 Decadal Survey) as having "significant promise for shedding light on dark energy". The LSST would be able to create weak gravitational lensing maps of over 10,0000 square degrees of the sky as well as discovering and monitoring the light curves of thousands of moderate redshift supernovae. Application of these techniques would go a long way towards understanding the nature of dark energy and dark matter and thus help to lift the veil on the ultimate destiny of the universe.

2.3. A 21st Century Frontier of Discovery: The Physics of the Universe

This report, issued in 2004 February presented a Federal cross-agency strategic plan for "discovery at this intersection of physics and astronomy." It is a Federal response to the 2002 NRC report "Connecting Quarks with the Cosmos" discussed in the previous paragraph. One of the top level recommendations of this report for the theme of dark energy also strongly endorsed the LSST concept:

> *"A high-priority independent approach to place constraints on the nature of Dark Energy will be made by studying the weak lensing produced by Dark Matter. This is a scientific goal of the LSST. Significant technology investments to enable the LSST are required, and NSF and DOE will begin technology development of detectors, optical testing and software algorithms leading to possible construction with first operations in 2012. NASA will contribute their expertise as appropriate."*

2.4. Dark Energy Task Force

The Dark Energy Task Force (DETF) was established by the Astronomy and Astrophysics Advisory Committee (AAAC) and the High Energy Physics Advisory Panel (HEPAP) as a joint sub-committee to advise the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation on future dark energy research. The report, completed in June, 2006, recommended that the dark energy program include a combination of techniques: baryon acoustic oscillations (BAO), galaxy cluster counting (CL), supernovae (SN), and weak gravitational lensing (WL). A unique feature of LSST amongst the other Dark Energy experiments is that it can address all four techniques with a single data set. The DETF, in order to avoid selecting a specific design, referred to a generic ground-based survey telescope as a Large Survey Telescope (LST). The report recommended that because JDEM, LST, and SKA all offer promising avenues to greatly improved understanding of dark energy, research and development required to optimize the programs and to address remaining technical questions and systematic-error risks should be supported.

2.5. Particle Physics Project Prioritization Panel

In 2008, P5 (the Particle Physics Project Prioritization Panel), at the request of the Office of High Energy Physics of the Department of Energy and the National Science Foundation, developed a plan for US particle physics for the coming decade. This report was submitted to the High Energy Physics Advisory Panel. It strongly recommended DOE support for the ground-based LSST program, in coordination with NSF, for all funding scenarios considered by the panel, with the level of support dependent on the overall program budget. Significantly, this P5 report to HEPAP ranked LSST ahead of new neutrino experiments. HEPAP approved the P5 recommendations. The report recognized that not only is LSST unique in the large number of simultaneous independent probes of dark energy, but also in its ability to detect any anisotropy in the distribution of dark energy. This burgeoning convergence of the high energy physics and cosmology communities around LSST as the "machine of choice" to address new physics is a significant development and bodes well for this interdisciplinary collaboration.

3. The Four Science Drivers for the LSST and Synergy with other Major Projects

The scope and power of the survey that the LSST will carry out enables an extremely broad range of scientific investigations. An in-depth presentation of the science capabilities and examples of specific programs may be found at http://www.lsst.org/overview/overview_v1.0.pdf We note that current and planned surveys, including the University of Hawaii project Pan-STARRS and the Subaru Hyper Suprimecam survey, are important and valuable precursors to the LSST survey.

In this section we focus on four main science themes of the LSST survey:

1. Constraining Dark Energy and Dark Matter
2. Taking an Inventory of the Solar System
3. Exploring the Transient Optical Sky
4. Mapping the Milky Way

3.1. Constraining Dark Energy and Dark Matter: Synergy with JDEM

Dark energy affects the cosmic history of the Hubble expansion as well as the cosmic history of mass clustering. If combined, different types of probes of the expansion history and structure history can lead to percent level precision in dark energy parameters. This is because each probe depends on the other cosmological parameters or errors in different ways. These probes range from cosmic shear, baryon acoustic oscillations, supernovae, and cluster counting -- all as a function of redshift. Using the cosmic microwave background (CMB) as normalization, the combination of these probes will remove degeneracies and yield the needed precision to distinguish between models of dark energy. LSST is the only “Stage IV” [in the language of the DETF] facility that will use more than two of the many types of probes of dark energy. Due to its wide-deep sky coverage, LSST will also detect anisotropy in the dark energy, if it exists. Some proposed JDEM facilities will extend 20,000 square degree coverage to the near IR, complimenting LSST’s optical data for determination of distances to galaxies via color-redshift. Thus, LSST and the planned Joint Dark Energy Mission of NASA and DOE, or the European space mission Euclid, can be powerful complements of one another.

Because of its deep-wide survey in six bands, LSST will pursue four types of probes of dark energy *with the same survey data*:

- Gravitational weak lensing of galaxies vs redshift, which probes both the evolution of structure over cosmic time and dimensionless ratios of distances vs cosmic time, thereby setting multiple independent strong constraints on the nature of dark energy. Distant galaxies are moved on the sky and systematically distorted by the “cosmic mirage” of foreground mass concentrations. Cosmology enters in the relative distances as well as the evolution of mass structure.

- The interplay between gravity and gas pressure in the very early universe has been demonstrated to imprint a characteristic physical scale on the clustering properties of galaxies at all epochs. This physical scale provides cosmologists with a standard ruler. By measuring the corresponding angle on the sky of these so-called "Baryon Acoustic Oscillations" as a function of redshift, we get angular diameter distances. These distances and redshifts allow us to constrain the expansion history of the universe and the cosmological parameters which govern this expansion.

- The redshift distribution of hundreds of thousands of large clusters of dark matter (via weak gravitational lensing combined with the optical data) are a sensitive probe of the equation of state of dark energy. This is a "standard volume" test. In particular, the distribution of shear peaks can be compared with n-body predictions. Like the supernova probe of dark energy, this technique has astrophysical systematics which will have to be understood if it is to be fully competitive with WL and BAO.

- A million supernovae are a useful complementary technique for probing the recent cosmic era when dark energy becomes dominant. Type Ia supernovae may be used as distance indicators if they are "standard candles." A fundamental open question is whether these supernovae are standard candles at the level of accuracy required for Stage-IV projects. A primary goal of the LSST supernova analysis program will be to detect systematics affecting the interpretation of supernova data for cosmology, while at the same time providing constraints on cosmological parameters. This will be feasible because the extremely large sample size of the LSST supernova database allows for multiple parameter fits, which can self-calibrate systematics in ways not accessible to current or other planned surveys.

3.2. Taking an Inventory of the Solar System

A small number of Earth-orbit crossing asteroids will ultimately strike the Earth's surface. The U.S. Congress mandated that by 2008, 90% of the near-Earth asteroids (NEAs) with diameters greater than 1 km be discovered and their orbits determined. Impacts of NEAs of this size have the potential to change the Earth's climate and cause mass extinctions, such as the one credited with killing the dinosaurs. A 2003 NASA report estimates conservatively that with current search techniques, about 70% of the NEAs with diameters larger than 1 km will be cataloged by 2008. This same report quantifies the risk of impacts by smaller bodies, and recommends as a reasonable next goal reduction of the residual hazard by another order of magnitude. Achieving this goal would require discovery of about 90% of the potentially hazardous asteroids (PHAs) down to diameters of about 140 m. Modeling suggests that the LSST is capable of finding 90% of the PHAs with diameters larger than 140 m within ten years. It is unlikely that any other currently planned facility could achieve this goal within a decade or two

The LSST can also make a major contribution to mapping Kuiper Belt Objects (KBOs). The orbits of KBOs provide a fossil record of the early history of the solar system; their eccentricities and inclinations contain clues to past perturbations by giant planets. The sizes of the KBOs hold clues to the accretion events that formed them and to their subsequent evolution through collisional grinding, etc. The compositions of KBOs are varied and correlated with their dynamical state. Light curves can be used to constrain the angular momentum distribution and internal strengths of the bodies. A more complete sample of KBOs and determination of their properties can assist with selecting targets for future NASA missions. The LSST survey will provide the color-magnitude-orbital distribution for all bright ($r < 24$) KBOs. The 100 or so observations obtained for each bright KBO will yield light curves for many thousands of KBOs,. A fraction of the observing time will be devoted to continuous observations in the ecliptic. This same mode of observation will be used to study variable and transient objects.

3.3. Exploring the Transient Optical Sky

The LSST will open a new window on the variable sky. Recent surveys have shown the power of variability for studying gravitational lensing, searching for supernovae, determining the physical properties of gamma-ray burst sources, etc. The LSST, with its repeated, wide area coverage to deep limiting magnitudes will enable the discovery and analysis of rare and exotic objects such as neutron star and black hole binaries, gamma-ray bursts and X-ray ashes, at least some of which apparently mark the deaths of massive stars, AGNs and blazars, and very possibly new classes of transients, such as binary mergers and stellar disruptions by black holes. It is likely that the LSST will detect numerous micro-lensing events in the local group and perhaps beyond. The LSST would provide alerts for concerted monitoring of these events, and open the possibility of discovering planets and obtaining spectra of lensed stars in distant galaxies as well as our own. LSST can also provide multi-wavelength monitoring over time of objects discovered by the Fermi Gamma-Ray Space Telescope and the proposed Energetic X-ray Imaging Survey Telescope (EXIST). With its large aperture, the LSST is well suited to conducting a Deep Supernova Search in selected areas. LSST will also provide a powerful new capability for monitoring periodic variables, such as RR Lyrae stars, which can be used to map the Galactic halo and intergalactic space to distances exceeding 400 kpc. Since LSST extends time-volume space a thousand times over current surveys, the most interesting science may well be the discovery of new classes of objects.

Exploiting the capabilities of LSST for time domain science requires large area coverage to enhance the probability of detecting rare events; time coverage, since light curves are necessary to distinguish certain types of variables and in some cases infer their properties (e.g. determining the intrinsic luminosity of supernovae Type Ia depends on measurements of their rate of decline); accurate color information to assist with the classification of variable objects; good image quality to enable differencing of images, especially in crowded fields; and rapid data reduction and classification in order to tag interesting objects for spectroscopic and other follow up with separate facilities. Time scales ranging from about1 min (to constrain the properties of fast faint transients such as those recently discovered by the Deep Lens Survey) to10 years (to study long-period variables and quasars) should be probed over a significant fraction of the sky. It should be possible to measure colors of fast transients, and to reach r about 24 mag in individual visits. Fast reporting of likely transients to the community is required in order to facilitate follow-up observations.

3.4. Mapping the Milky Way

The LSST is ideally suited to answering two basic questions about the Milky Way Galaxy: What is the structure and accretion history of the Milky Way? What are the fundamental properties of all the stars within 300 pc of the Sun?

Standard models posit that galaxies form from seeds planted by the Big Bang with accretion over time playing a significant role in determining their structure. Detailed study of the Milky Way can provide rigorous tests of these ideas, and the LSST will be able to map the 3-D shape and extent of the halo of our Galaxy. Specifically, the LSST will detect F turn-off stars to distances of 200 kpc; isolate stellar populations according to color; and determine halo kinematics through measurement of proper motions at distances exceeding 10 kpc. The LSST dataset can be used to identify streams of stars in the halo that are thought to provide a fossil record of discrete accretion events. The LSST in its standard surveying mode will be able to detect RR Lyrae variables and classical novae at a distance of 400 kpc and hence explore the extent and structure of our own halo out to half the distance to the Andromeda Galaxy. The proper motions and photometric parallaxes for these stars can be used to characterize the properties of the dark matter halo in which the Milky Way is embedded. The LSST will survey a significant fraction of the Galactic plane, including the Galactic center, and will obtain unprecedented data for studies of star-forming regions.

Is our solar system with its family of planets unique? Or are there many more that contain Earth-like planets within the so-called habitable zone? How do solar systems form? Detailed exploration of our local neighborhood is key to answering these questions. The LSST will obtain about 1 milli arcsecond parallax measurements of hydrogen-burning stars to a distance of 300 pc and of brown dwarfs to tens of parsecs. These measurements will provide basic information on candidate stars that merit further study in the search for companions, including planets. Residuals from the fits for position, proper motions, and parallax will be searched for the signature of Keplerian motion to identify stars and brown dwarfs with companions and provide fundamental estimates of the mass of the primaries. LSST data will be used to determine the initial mass functions for low-mass stars and sub-stellar mass objects and to test models of brown dwarf structure. The age of the Galactic disk can be inferred from white dwarf cooling curves.

3.5 Synergy Between LSST and other Major Projects

LSST will greatly benefit from data from other precursor and coeval facilities aside from Pan-STARRS and Subaru HSC, and will in turn complement and support research with these facilities both on the ground and in space. For example, the Gaia survey will provide calibration checks at the bright end for proper motions and trigonometric parallax measurements by LSST, and LSST will extend the Gaia survey four magnitudes deeper. LSST has the potential to measure the electromagnetic signal that accompanies a burst of gravitational wave emission, thereby providing a definite position on the sky for the emitting system, which is crucial for follow-up observations of detections by LISA and LIGO. The huge samples of various astronomical source populations observed by LSST will yield extremely rare objects for follow-up by powerful facilities such as JWST and GSMT.

Other examples of synergy between LSST and other facilities are noted earlier in this section 3 as well as in section 4.5.1 of the LSST paper at http://www.lsst.org/overview/overview_v1.0.pdf .

4. LSST Education and Public Outreach Opportunities

This section is from http://www.lsst.org/Meetings/AAS/Jan2006/Jacoby.pdf .

Education and public outreach (EPO) activities figure prominently in all of AURA's centers. The potential for EPO with the LSST is far reaching. The LSST data will be open to the public and to scientists around the world; anyone with a web browser will be able to access and analyze images, data products, tools, and educational materials. The LSST EPO group will be developing NVO-compliant data management strategies for the public. Below we describe ideas being explored in four areas: Visualizing LSST observations in science centers; exploring real scientific data and demystifying its meaning in formal and informal education venues; creating partnerships of public, amateur, and professional astronomers to broaden participation in the cutting-edge research enabled by LSST; and using internet-based technology to empower the public's participation in scientific investigations of the nature of our universe.

4.1. Visualization

By remapping the visible sky every few nights, the LSST will open a movie-like window to the changing universe. In partnership with the American Museum of Natural History (AMNH), the project is exploring ways to use the power of LSST images to convey excitement and information in science centers, planetariums, and on the web. Several venues are being considered to enable a digital representation of the universe, allowing three dimensional flybys and time lapse explorations which the user could control through touch panels and interactive kiosk programming. A first step in this effort is to import precursor data into the Digital Universe, an AMNH project producing a catalogue database which is then visualized into a 3-dimensional atlas that can be interactively explored. The Kitt Peak National Observatory Visitor Center will serve as a partner in our visualization efforts, replicating venues for smaller centers.

4.2. Data Driven Education and Outreach

A second thread of the LSST EPO program is the exploration of real data in formal and informal education settings. By placing LSST's data into the AMNH Digital Universe, the project will have laid the cornerstone for its inclusion in, for example, sky shows and interactive displays that can be replicated at smaller installations. In formal settings, Hands-On-Universe (HOU), the NOAO Teacher Leaders in Research Based Science Education (TLRBSE) program, and the SDSS outreach efforts have all brought authentic exploration into the classroom. The LSST project intends to offer professional development through online courses and integration of appropriate LSST science themes into textbooks. Students will benefit from LSST data packaged for science fair projects and independent research.

4.3. Creative Partnerships

It is estimated that the LSST will generate tens of thousands of alerts a night of moving or changing objects. This will expand the volume of discoveries requiring confirmation and follow-up to gigantic proportions. Creative partnerships involving the interested public, the amateur community, and professional astronomers could participate in the follow-up of these discoveries. The IT industry will also be involved. Already, Google is collaborating with LSST.

The Las Cumbres Observatory Global Telescope Network will be instrumental in providing the necessary telescopes for follow up observations. This network will consist of six or seven 2-m class telescopes, longitudinally distributed and placed in both the northern and southern hemisphere. Their primary mission will be time variable astrophysics, providing follow-up for large survey telescope projects including Pan-STARRS and LSST. The LSST EPO group is working to develop ways of effectively providing this powerful network of telescopes to support its outreach efforts.

4.4. Emerging Technologies

When LSST data begins to flow sometime in the next decade, it is safe to predict that many technologies unfamiliar to most of us now will then be commonplace. Custom web portals and portable devices for two-way interaction with text, graphics, data and video will be routine, but there will still be a bandwidth challenge. The data rates required by LSST to bring the universe into home and school environments are achievable. Color JPEGS at 0.4 arcsecond resolution of the static deep sky will require only 180GB, downloadable in 30 minutes on a 1GB link. Dynamic graphics overlays from metadata (time varying or moving objects) require little bandwidth, and tools for public query of the LSST dynamic sky database will be provided. The LSST Outreach efforts will make use of the powerful technology of the future, facilitating the investigation and appreciation of the dynamic universe by everyone.

5. LSST as a Driver of Innovation

Astronomy is undergoing a revolution in the way we probe the universe and the way we try to answer fundamental questions. New technology is enabling this revolution. For example, novel detectors are opening new windows on the universe, creating unprecedented volumes of high quality data. Major advances in computing technology are helping to keep up with this data explosion. These technological advances are driving a shift in the way science is done in astronomy and astrophysics. Huge surveys of the sky over a wide range of wavelengths can now be analyzed statistically for low-level but highly significant correlations. LSST is the lighthouse project in this revolution in astronomy; solutions to technological challenges of designing and constructing LSST and the subsequent computational challenges of handling its data flow are already having spin-off effects in broader areas of technology and “big data” science.

Examples of the extraordinary engineering, technological, and computational challenges that are being met in the realization of the LSST include: the fabrication of large, high-precision aspheric optics; construction of a huge, highly-integrated array of sensitive, wide-band imaging sensors; and the operation of a data management facility handling tens of terabytes of data each day. The design and development effort includes structural, thermal, and optical analyses of all key hardware subsystems, prototyping and development of data management systems, and extensive systems engineering studies. To validate system performance, full end-to-end simulations are being done. Over 100 technical personnel at a range of institutions are currently engaged in this program. LSST R&D has led to a new generation CCD which is highly segmented, low noise, and sensitive from the UV to the near IR. The rapid cadence of the LSST observing program will produce about 30 TB per night, leading to a total database over the ten years of operations of 60 PB for the raw data, and 30 PB for the catalog database. The total data volume after processing will be about 100 PB, processed using 100 TFlops of computing power. Processing such a large volume of data, converting the raw images into a faithful representation of the universe, automated data quality assessment, and archiving the results in useful form for a broad community of users is a major challenge.

The linkage between data-driven modeling and discovery has entered a new paradigm. The rate of acquisition of data in many scientific disciplines is accelerating and causing a very challenging – and exciting - data avalanche which holds the promise to greatly advance our knowledge and understanding of the universe we live in at all scales in space and time, from the fundamental constituents of matter to the large scale structure of the universe, from the instant of the Big Bang to the age of the Universe. With this accelerated advance in data generation capabilities, we will require novel, increasingly automated, and increasingly more effective scientific knowledge discovery systems.

Finally, it is useful to itemize just a few of the data products that the LSST scientific database and archive will include and make accessible to the entire astronomical community as a demonstration of why AURA supports and participates in this project as part of its mission to *"to promote excellence in astronomical research by providing access to state-of-the-art facilities"*. The science archive itself will be built up from 400,000 16 megapixel images *per night of operation* (for 10 years), comprising 60-100 PB of pixel data. Within the online data base users will find the following:

- Over 100 database tables
- Image metadata consisting of 675 million rows
- A source catalog of with a trillion lines
- An object catalog with 22 billion rows each with 200+ attributes
- A moving object catalog with 10 million rows
- A variable object catalog with 100 million rows
- An alerts catalog. Alerts issued worldwide within 60 seconds.
- Calibration, configuration, processing, and provenance metadata

And the LSST will be even more than a powerful new resource for the entire astronomical community offering an entirely novel way of doing science. The LSST is a technology driver and a prime example for other fields of science trying to absorb and analyze massive data bases.