LSST: Taking Inventory of the Solar System

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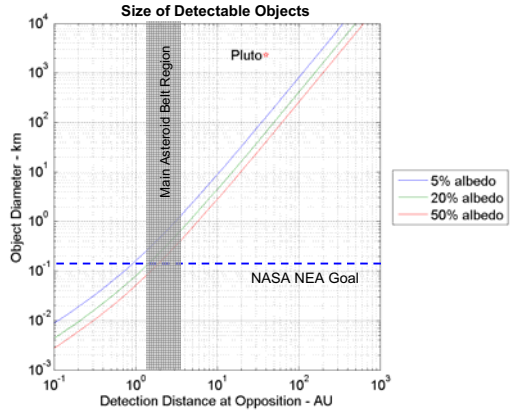
LSST is a wide-field survey instrument that addresses key scientific priorities, including planetary science objectives, of a number of committees commissioned by the National Academy of Sciences. The baseline LSST design is an 8.4m aperture telescope with a 3.2 giga-pixel focal plane array that will allow detections of point sources as faint as magnitude 24.8 by co-adding back-to-back 15-second images comprising 9.6 square degrees each. By visiting each field twice in a night and revisiting on 3-5 well-spaced nights per lunation, the survey will accumulate a massive catalog of solar system objects. This will include upwards of 80% of the potentially hazardous asteroids larger than 140m diameter within 10 years, making a significant contribution towards addressing a recent Congressional directive to NASA to catalog 90% of such objects. LSST will catalog millions of main-belt asteroids and perhaps 20,000 trans-Neptunian objects, providing ancillary information about color and photometric variability for many of these. Pluto-like objects will be detectable at heliocentric distances beyond 300 AU. Long-period comets will generally be discovered far earlier than previously possible, enabling photometric studies uncontaminated by nucleus activity and the testing of Oort cloud population models.

LSST Solar System Science

LSST, with its unprecedented power for discovering moving objects, will make a giant leap forward in the Solar System studies. The baseline LSST cadence will result in orbital parameters for several million moving objects, with the following science dividends:

1. Approximately a **factor 25 increase in the number of discovered objects** in the solar system, across all orbital regimes. Orbital parameters will be derived for virtually all objects. (See Moving Object Processing System discussion at right.) Doubtlessly, many objects on extraordinary or exotic orbits will be discovered.
2. In terms of size, LSST will push completeness down by a factor of three relative to current all-sky moving object surveys, **observing objects as small as 100m in the main belt and <100km in the Kuiper Belt**. Pluto-sized objects will be detected as far out as 300 AU. (See figure at right.) A special "Deep Drilling" survey mode will detect KBOs only tens of kilometers in diameter, extending the estimated size frequency distribution and testing Solar System formation theories.
3. LSST, with its ugrizY filters, will observe most objects at several wavelengths, providing **accurate colors for a substantial fraction of discoveries**. This will enable constraints on the dynamical-chemical correlation among populations, revealing the nature of collisional and dynamical evolution among various populations.
4. After the nominal ten-year LSST survey, photometric variability information will be available for most objects, allowing **spin state and shape estimation for up to two orders of magnitude more objects than presently known**. This will leverage physical studies of asteroids, constraining the size-strength relationship, which has important implications for the internal structure (solid, fractured, rubble pile) and in turn the collisional evolution of the asteroid belt.

Size of Detectable Objects

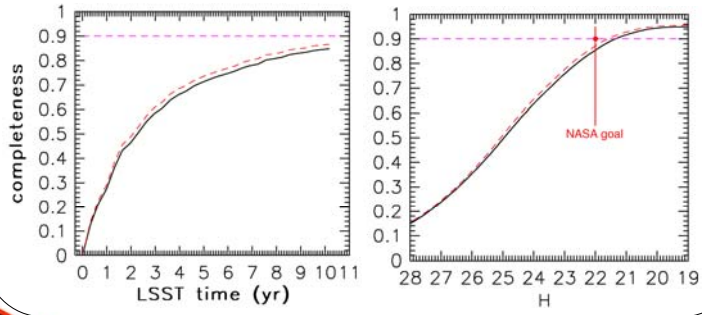


LSST will detect solar system objects at great distances, significantly expanding the outer limits of the known solar system. The above plot indicates the distance at which moving objects can be detected at full phase assuming a detection limit of V=24.8.

From Detections to Orbits

The Moving Object Processing System (MOPS) is part of a collaborative development effort with the Pan-STARRS project. The tremendous increase in data volume anticipated from LSST will pose numerous significant technical challenges in extracting moving object detections and linking them across nights, months and years to form reliable orbits. Tree-based algorithms for multi-hypothesis testing of asteroid tracks can help solve these challenges by providing the necessary 1000 fold speed-up over current approaches while recovering 95% of the underlying objects.

Completeness of 140 meter diameter NEOs as a function of survey time and absolute magnitude

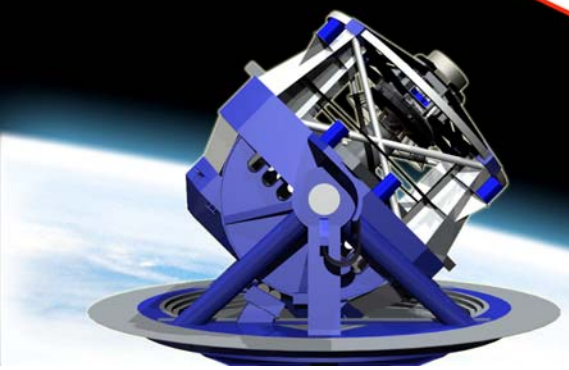


The Impact Hazard

In December 2005 Congress directed NASA to implement a near-Earth object survey that would catalogue 90% of NEOs larger than 140m. **LSST will discover 80-90% of potentially hazardous asteroids larger than 140m**, thus approaching and perhaps reaching the NASA goal in ten years of surveying, and thereby reducing the impact threat posed by undiscovered objects by more than an order of magnitude. In the process, LSST will assess the hazard to Earth from asteroid impacts by constraining the orbital and size distribution of the near-Earth population, allowing concrete estimates of the impact frequency as a function of size.

Recent survey simulations (See Pinto et al. poster, this session) reveal that LSST will have excellent efficiency in detecting moving object detections. The plots at left assume that an NEO is added to the catalog of orbits if it has been observed at least twice per night on at least three nights. Moreover, to facilitate linkage, the three nights must be within a 40 day period and two nights must be within a seven day period. The lower curves indicate the completion based on the latest simulation and the upper curves include an enhanced higher air mass search of the high declination region of the ecliptic.

The survey results indicate that most discovered objects will be very well observed, with each search region visited an average of six times per lunation, leading to a median of 40 nights of observation in the ten-year survey for cataloged NEAs.



The effort to build the Large Synoptic Survey Telescope is overseen by the LSST Corporation, a non-profit 501(c)3 corporation formed in 2003, with headquarters in Tucson, AZ. The LSST research and development effort is funded in part by the National Science Foundation under Scientific Program Order No. 9 (AST-0551161) through Cooperative Agreement AST-0132798. Additional funding comes from private donations, in-kind support at Department of Energy laboratories and other LSSTC Institutional Members.

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