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# Lincoln Near-Earth Asteroid Program (LINEAR)

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**The Lincoln Near-Earth Asteroid Research (LINEAR) program has applied electro-optical technology developed for Air Force Space Surveillance applications to the problem of discovering near-Earth asteroids (NEAs) and comets. This application is natural due to the commonality between the surveillance of the sky for man-made satellites and the search for near-Earth objects (NEOs). Both require the efficient search of broad swaths of sky to detect faint, moving objects. Currently, the Air Force Ground-based Electro-Optic Deep Space Surveillance (GEODSS) systems, which operate as part of the worldwide U.S. space surveillance network, are being upgraded to state-of-the-art charge-coupled device (CCD) detectors. These detectors are based on recent advances made by MIT Lincoln Laboratory in the fabrication of large format, highly sensitive CCDs. In addition, state-of-the-art data processing algorithms have been developed to employ the new detectors for search operations. In order to address stressing space surveillance requirements, the Lincoln CCDs have a unique combination of features, including large format, high quantum efficiency, frame transfer, high readout rate, and low noise, not found on any commercially available CCD. Systems development for the GEODSS upgrades has been accomplished at the Lincoln Laboratory Experimental Test Site (ETS) located near Socorro, New Mexico, over the past several years. Starting in 1996, the Air Force funded a small effort to demonstrate the effectiveness of the CCD and broad area search technology when applied to the problem of finding asteroids and comets. This program evolved into the current LINEAR program, which is jointly funded by the Air Force Office of Scientific Research and NASA. LINEAR, which started full operations in March of 1998, has discovered through September of 1999, 257 NEAs (of 797 known to date), 11 unusual objects (of 44 known), and 32 comets. Currently, LINEAR is contributing ∼70% of the worldwide NEA discovery rate and has single-handedly increased the observations submitted to the Minor Planet Center by a factor of 10. This paper covers the technology used by the program, the operations, and the detailed results of the search efforts.**

*Key Words:* **asteroid; comet; data reduction techniques; image processing; instrumentation.**

## INTRODUCTION

The population of Earth-crossing asteroids, or near-Earth asteroids (NEAs), with diameters larger than 1 km has been reasonably estimated in recent years to be as low as 750 (Rabinowitz *et al.* 2000) or as high as 2100 (Morrison *et al.* 1992). Asteroids with diameters greater than 100 m is estimated to be between 30,000 and 300,000. Asteroids with diamaters exceeding 100 m can cause considerable regional damage in a collision with Earth, and asteroids with diameters exceeding 1 km may cause global effects (Chapman and Morrison 1994). Damage from impacts in an ocean can be considerably enhanced in coastal areas by the creation of tsunamis (Morrison *et al.* 1994). Currently, only a fraction of the NEA population is known—about 43% of the asteroids with diameters larger than 1 km (assuming the lowest estimate of 750) and a considerably smaller fraction for asteroids less than 1 km. The first step toward protecting Earth is to develop a system that will find and catalog all possibly threatening asteroids, and track new comets entering the inner Solar System (Harris 1998). The Lincoln Near Earth Asteroid Research (LINEAR) system was constructed to respond to that need.

Historically, asteroid search programs relied on traditional photographic plate techniques. However, in recent years, the use of electronic imaging techniques using charge-coupled devices (CCDs) have substantially changed the way the majority of asteroids are detected. In order for CCD-based asteroid searches to achieve their full potential, a combination of low noise, high sensitivity, and fast readout capabilities is needed. In support of the Air Force Space Surveillance program that tracks Earth-orbiting satellites, Lincoln Laboratory has developed CCDs that address the more stressing requirements associated with the search of large portions of the sky for satellites. This technology has been developed for the operational space surveillance system called the GEODSS (Ground-based Electro-Optic Deep Space Surveillance) system. These CCDs are back illuminated for higher quantum efficiencies, have very low readout noise, and have a frame transfer design that eliminates the slow readout problem (Stokes *et al.* 1996). This unique combination of features was designed to address the space surveillance mission, but also makes these CCDs very well suited for asteroid search.

## LINEAR SYSTEM AND OPERATIONS

Advanced CCD focal planes have been installed in a new generation of cameras and have undergone a series of tests at Lincoln Laboratory's Experimental Test Site (ETS) on the White Sands

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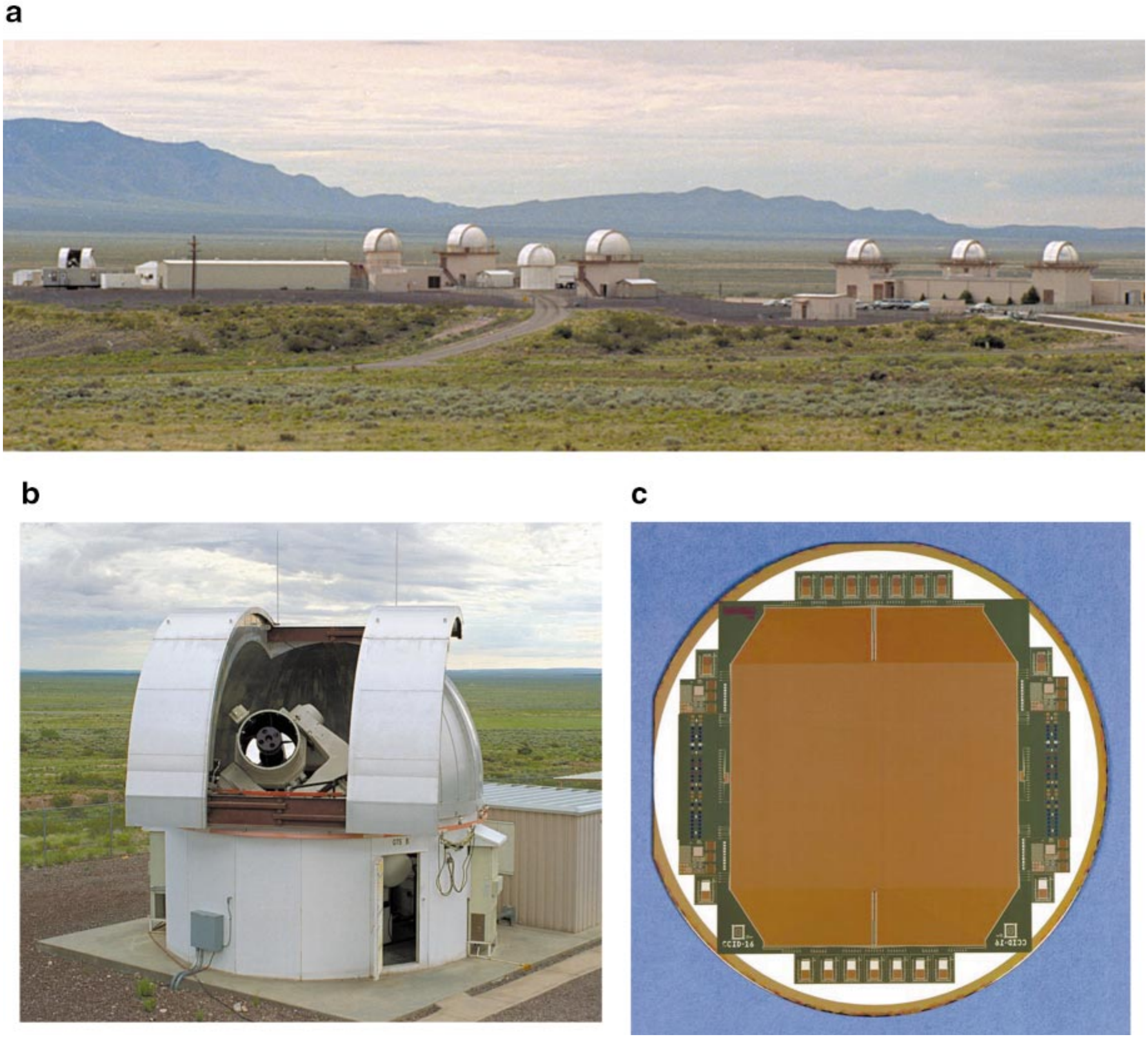

**FIG. 1.** (a) Experimental test site near Socorro, NM. The LINEAR telescope is housed in the far-left dome. (b) LINEAR Telescope. (c) Lincoln Laboratory CCD used in LINEAR System.

Missile Range near Socorro, New Mexico, shown in Figs. 1a and 1b. Specifics relating to the advanced focal plane were reported at the Space 96 meeting (Stokes *et al.* 1996) and are summarized here. The focal plane, shown in Fig. 1c, contains an array of 2560 × 1960 pixels and has an intrinsic readout noise of only a few electrons per pixel. The CCDs are constructed using a back illumination process, which provides peak quantum efficiency exceeding 95%, and solar weighted quantum efficiency of 65%. Due to the frame transfer feature the image transfer time from the imaging area into the frame buffer is only several milliseconds.

Figure 2 displays a block diagram of the LINEAR system as it exists at the ETS today. The core of the LINEAR detection system has not changed significantly in recent years. It was described at the Space 98 meeting (Viggh *et al.* 1998), and summarized here. Essentially, five frames of data corresponding to the

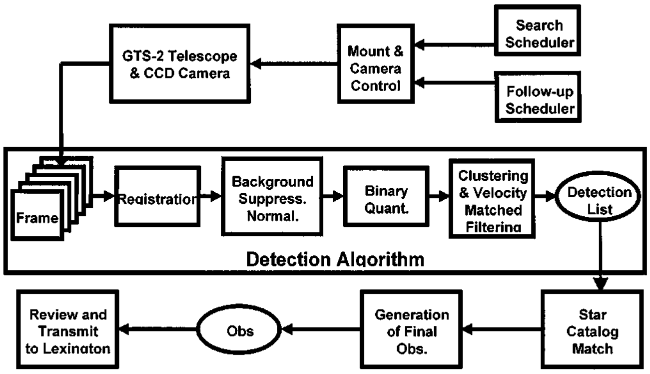

**FIG. 2.** Block diagram of ETS system used to acquire asteroid data and detection algorithm.

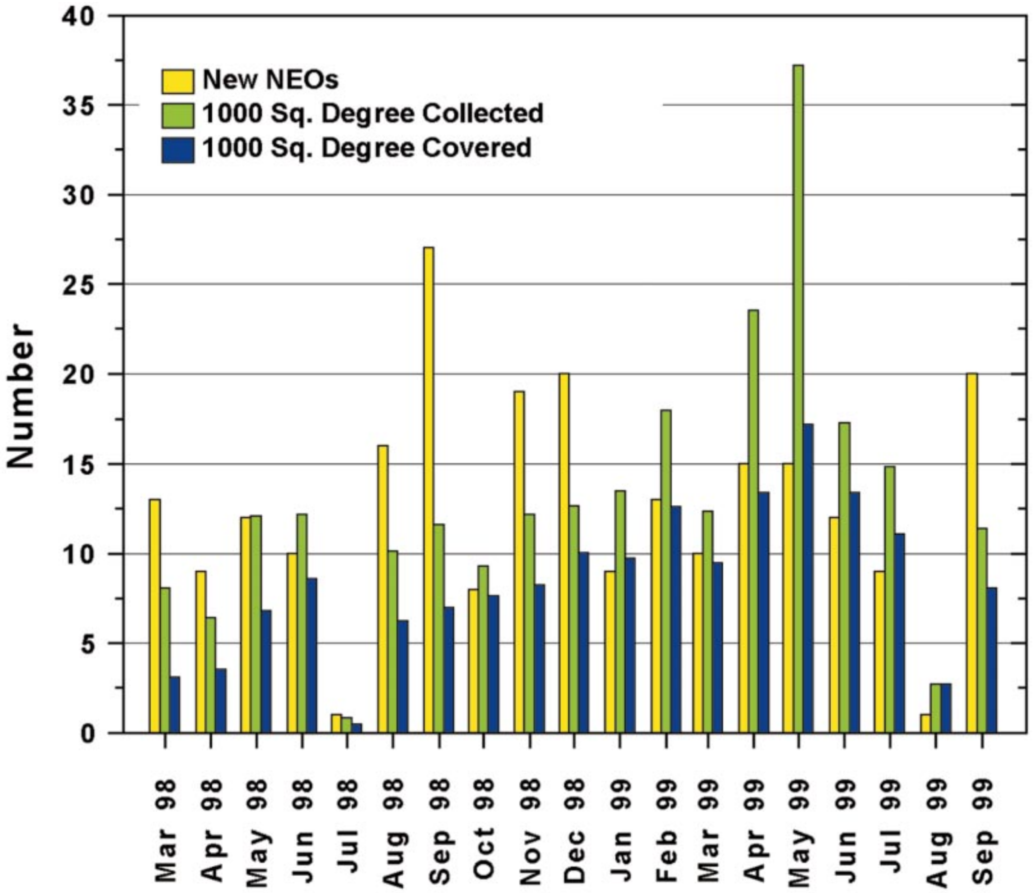

**FIG. 3.** The amount of sky covered, data collected, and NEAs discovered by month. The difference between the sky covered and the data collected shows the degree to which portions of the sky were covered multiple times during the month.

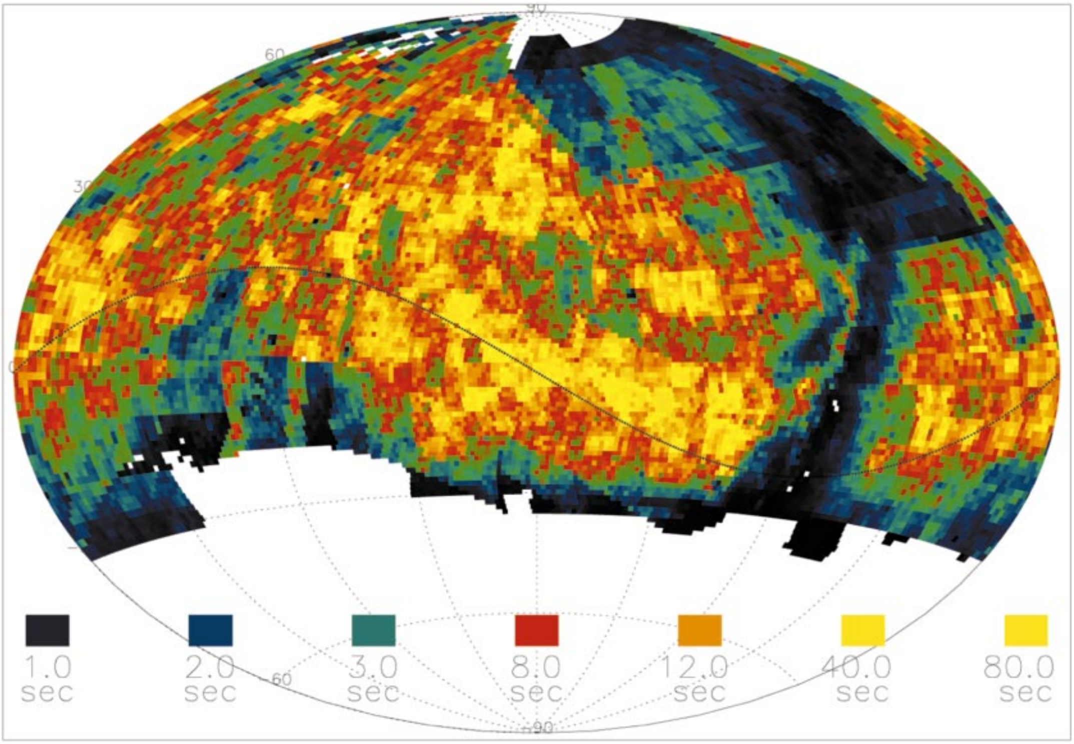

**FIG. 4.** Composite LINEAR sky coverage for October 1998–September 1999.

same part of the sky are collected at approximately 30-min intervals. The frames are aligned, then background noise is suppressed via a fixed threshold. The resulting binary quantized data is further processed for candidate streaks and their velocities determined. In general, fast moving objects ($>0.4^\circ$/day) and medium moving objects ($>0.3^\circ$/day, $<0.4^\circ$/day) are automatically flagged as potential NEOs. Slow moving objects ($<0.3^\circ$/day) are more likely to be main belt asteroids but are checked by an analyst for potential NEOs. After comparison to a star catalog for position and magnitude information, all observations for slow-, medium-, and fast-moving objects are sent to the Minor Planet Center (MPC), albeit at different priority levels, to be used for locating potential NEOs or for updating known asteroid positions.

While there have been some improvements in the detection system and thresholding algorithm since the Space 98 meeting, two system changes are responsible for most of the enhancements in the number of detections at ETS: the unbinning of pixels and the addition and continued improvement of the search scheduler and the follow-up scheduler. Prior to June 1999, all data was collected in a $2 \times 2$-binned mode that incurs a slight detection loss. Following a data processing upgrade it became feasible to use an unbinned mode. The resulting improvement in sensitivity is reflected in the detection performance charts presented in the next section.

The search scheduler and follow-up scheduler was the other area of significant improvement. The search scheduler algorithm is used to translate a description of the area of sky to be searched into a sequence of right ascension (RA) and declination (DEC) field center positions. The search area is described in terms of degrees from opposition, and northern and southern limits. The pattern is then automatically laid out to minimize telescope step and settle times, and also orders the fields to account for the rotation of Earth throughout the course of a night.

The follow-up scheduler performs a similar task using the predicted RA and DEC positions of medium movers and NEO candidates as the input. A Vaisala orbit predictor on the MPC web page is automatically accessed to predict the RA and DEC positions of each object for the approximate time when the follow-up observing will be done. Next, the predicted positions of the NEO candidates on the confirmation page are also automatically downloaded. The predicted medium mover and NEO candidates are combined and follow-up observations of these positions are then scheduled based on their locations in the sky to minimize telescope motion. An output file is then generated and fed directly into the telescope control software. Objects from the follow-up scheduler take precedence over the search scheduler.

The amount of revisit coverage during a given month has been reduced as the search program has matured, thereby resulting in an overall increase in coverage. Figure 3 shows a histogram of the amount of data collected and the amount of sky searched as a function of the month from March 1998 through September 1999. In May 1999, the large increase in square degrees of data collected was due to testing of a second LINEAR telescope utilizing a less sensitive engineering development CCD. Also, in June 1999 the LINEAR data processing system was upgraded, allowing for more fields to be stored and operation in the unbinned mode.

Early in the monthly observing cycle, the Moon is still bright during much of the night, and thus short integration sequences, typically 3 s, are taken over 600 fields (1200 square degrees) covering areas well away from opposition. As the month progresses toward new Moon, the search shifts closer to opposition and extends the integration period, typically to 11 s per image. Generally, 10,000–20,000 square degrees of data are collected per lunation. Since some portions of the sky near opposition are covered more than once during a single month; this yields about 8000–13,000 square degrees of sky visited during each month. Figure 4 displays the composite coverage of the LINEAR system during the 1-year period of October 1998–September 1999. This plot has been scaled to show a good-weather, background-corrected, single-frame equivalent integration time. Note that the LINEAR system is covering nearly the entire sky visible above our site's effective southern declination limit of $-35^\circ$, although some of those areas are being covered at shorter integration times and to shallower depths than others. The longest and deepest searches are concentrated along the ecliptic.

## LINEAR SEARCH RESULTS

The productivity of the LINEAR search can be seen from Table I, which contains a numerical summary of the LINEAR search observations covering calendar years 1997 and 1998 and monthly observations for 1999 through September. The data reported include the number of observations supplied to the Minor Planet Center, the number of NEAs and comets discovered, and the total number of discoveries credited to LINEAR, including main belt and other miscellaneous asteroid classes.

Appendix A details the orbital elements, magnitude information, and apparent motion at time of discovery of all 257

**TABLE I**

**Number of Observations Reported to the MPC and Resulting Discoveries (NEOs, Comets, and Asteroids) through 9/30/99**

| Lunar dark period | Obs sent to MPC | NEO discoveries | Comet discoveries | Total discoveries |
|---|---|---|---|---|
| 1/99 | 31,848 | 9 | 0 | 301 |
| 2/99 | 84,887 | 13 | 0 | 3,014 |
| 3/99 | 73,899 | 10 | 0 | 1,017 |
| 4/99 | 105,587 | 15 | 2 | 644 |
| 5/99 | 101,833 | 15 | 9 | 3,310 |
| 6/99 | 52,422 | 12 | 2 | 634 |
| 7/99 | 53,646 | 9 | 1 | 1,614 |
| 8/99 | 2,595 | 1 | 0 | 2 |
| 9/99 | 116,404 | 20 | 2 | 4,728 |
| Totals 1999 | 623,121 | 104 | 16 | 15,264 |
| Totals 1998 | 758,798 | 135 | 16 | 17,373 |
| Totals 1997 | 100,991 | 18 | 0 | 2,000 |
| Grand totals | 1,482,910 | 257 | 32 | 34,637 |

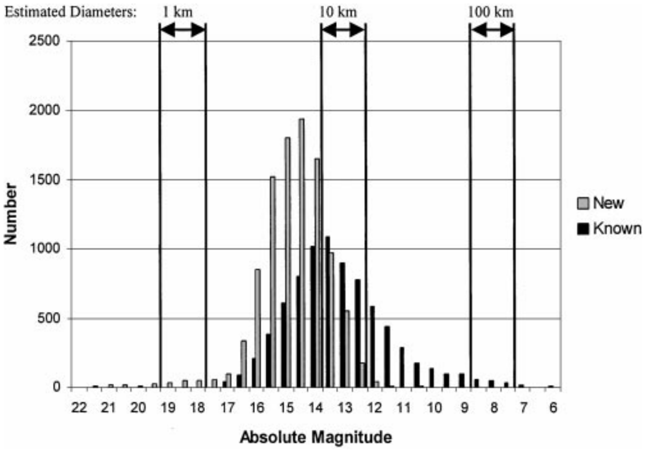

**FIG. 5.** Histogram of absolute magnitudes of all asteroids with MPC designations detected by LINEAR through September 1999.

NEAs discovered by LINEAR and the 11 asteroids discovered by LINEAR which have been deemed “unusual” by the Minor Planet Center. In addition, the 32 comets discovered by LINEAR during the same period are also listed.

Figure 5 shows a histogram of the absolute magnitude of all of the asteroids detected by LINEAR through September 1999, separating newly discovered and previously known objects. The shape of the histogram is determined from all detections for which an orbit is known, and therefore an absolute magnitude can be determined. The magnitude of the histogram is determined by scaling the curves to account for all of the detections that were either correlated to the known catalog or assigned a new designation. As can be seen, the LINEAR discoveries are generally fainter than the known population, the peak of the newly discovered objects being approximately one magnitude fainter.

LINEAR has become the single largest contributor of asteroid observations to the MPC. Table II summarizes the percentage of worldwide discoveries that LINEAR has made. PHAs are potentially hazardous asteroids, which are NEAs whose size and potential close approaches to Earth make them the most threatening of the NEA population. The list of PHAs is populated and maintained by the MPC. LINEAR currently accounts for nearly 70% of all NEA and PHA discoveries from March 1998 through September 1999. Overall, LINEAR has discovered 30% of the known NEAs and PHAs. This is impressive given that the other 70% of the catalog took over 100 years to discover. Also notable in Table II is the fact that since March 1998, LINEAR has found 19 of the 27 Aten asteroids discovered. Atens are difficult to detect since they have a mean distance from the Sun that is less than 1 AU. They are therefore best detected far from opposition.

**TABLE II**
**LINEAR Percentages of World Wide NEA Discoveries as of 9/30/99**

| Discovery | LINEAR | Total world wide | Percentage |
|---|---|---|---|
| NEAs | 257 | 797 | 32 |
| NEAs since 3/98 | 239 | 338 | 71 |
| NEAs > 1 km | 72 | 323 | 22 |
| NEAs > 1 km since 3/98 | 69 | 100 | 69 |
| PHAs | 64 | 196 | 33 |
| PHAs since 3/98 | 61 | 85 | 72 |
| Atens | 19 | 55 | 35 |
| Atens since 3/98 | 19 | 27 | 70 |

## FUTURE PLANS

Future plans for LINEAR include integrating a second telescope into the LINEAR detection system. The telescope with a temporary, front-illuminated CCD began sporadic testing in May 1999, and the nearly identical system with the permanent chip will become operational October 1999. This telescope will allow LINEAR to integrate longer to increase sensitivity, while maintaining coverage of large areas of the sky. New real-time data processing systems are currently under development that will remove certain constraints on the amount of data that can be collected in a single night, which will further increase the amount of data collected and sky covered. A third telescope system is also under development, primarily for Air Force applications, which will be operated on a noninterfering basis for follow-up of NEO candidates and other interesting objects. This third telescope will utilize a smaller format CCD (1024 × 1024), which supports a narrower field of view than the search system. The follow-up scheduler software system is being augmented to automate the use of these second and third telescopes in support of the wide area search units.

Future plans also include developing an automated system for detecting NEOs that are slow movers and that are easily overlooked in the mass of main belt asteroids. Currently, slow moving NEOs are isolated by an analyst. This method has resulted in the detection of three near Earth asteroids (1998 ME3, 1998 ML14, and 1998 XC9) in the past year.

## SUMMARY

The LINEAR program has been using Air Force-developed space surveillance technology to consistently search a large portion of the night sky for asteroids since March 1998. LINEAR is currently contributing over 70% of NEA discoveries worldwide. Future improvements to the LINEAR observing system should continue to increase the program’s productivity and contribution to the cataloging of dangerous NEOs.

## APPENDIX A: LINEAR DISCOVERIES

(From inception through September 1999)

This appendix includes three tables listing the 257 NEAs in Table AI, the 11 unusual objects in Table AII, and the 32 comets in Table AIII discovered

## TABLE AI
## NEAs Discovered by LINEAR through September 1999

| Provisional Designation | Incl (deg) | e | a (au) | H | V mag | L mag | vel | Disc date |
|---|---|---|---|---|---|---|---|---|
| 1999 Discoveries | | | | | | | | |
| 1999 SJ10 | 6.7 | 0.71 | 2.13 | 19.5 | 18.3 | 19.1 | 0.73 | 9 30 |
| 1999 SH10 | 9.6 | 0.13 | 1.10 | 22.7 | 17.4 | 17.5 | 1.86 | 9 30 |
| 1999 SG10 | 23.6 | 0.61 | 1.46 | 20.6 | 18.3 | 18.0 | 1.85 | 9 30 |
| 1999 SF10 | 1.2 | 0.25 | 1.28 | 24.2 | 18.5 | 18.9 | 1.45 | 9 30 |
| 1999 SE10 | 6.9 | 0.62 | 3.21 | 20.0 | 18.7 | 19.2 | 0.35 | 9 30 |
| 1999 SM5 | 5.2 | 0.69 | 2.30 | 19.1 | 15.7 | 16.4 | 4.15 | 9 28 |
| 1999 SL5 | 22.8 | 0.54 | 1.92 | 17.1 | 17.6 | 18.1 | 1.17 | 9 28 |
| 1999 RM45 | 10.9 | 0.64 | 1.68 | 19.3 | 18.7 | 19.1 | 1.38 | 9 14 |
| 1999 RL45 | 22.5 | 0.38 | 1.83 | 18.6 | 18.7 | 19.3 | 0.88 | 9 14 |
| 1999 RK45 | 5.9 | 0.77 | 1.59 | 19.8 | 18.8 | 18.3 | 1.10 | 9 13 |
| 1999 RQ36 | 6 | 0.21 | 1.13 | 20.9 | 15.8 | 15.2 | 1.40 | 9 11 |
| 1999 RK33 | 3 | 0.60 | 2.53 | 22.4 | 18.0 | 18.9 | 2.51 | 9 9 |
| 1999 RJ33 | 18.5 | 0.19 | 1.26 | 22.5 | 16.8 | 17.2 | 9.75 | 9 9 |
| 1999 RD32 | 6.6 | 0.78 | 2.62 | 16.3 | 17.3 | 18.3 | 0.77 | 9 8 |
| 1999 RC32 | 31 | 0.43 | 1.84 | 18.2 | 18.4 | 18.9 | 1.26 | 9 8 |
| 1999 RB32 | 3.9 | 0.57 | 2.43 | 19.8 | 15.9 | 16.4 | 3.65 | 9 8 |
| 1999 RA32 | 10.5 | 0.09 | 1.03 | 20.9 | 18.2 | 18.5 | 1.40 | 9 8 |
| 1999 RZ31 | 3 | 0.60 | 2.60 | 23.8 | 17.0 | 17.9 | 8.26 | 9 7 |
| 1999 RR28 | 7.1 | 0.65 | 1.88 | 18.4 | 18.7 | 19.7 | 0.64 | 9 7 |
| 1999 RN28 | 8.8 | 0.46 | 2.17 | 20.9 | 18.4 | 19.0 | 1.13 | 9 7 |
| 1999 PS3 | 3.6 | 0.49 | 2.04 | 21.7 | 18.3 | 18.9 | 2.09 | 8 11 |
| 1999 OR3 | 9.5 | 0.58 | 2.03 | 17.8 | 16.8 | 17.7 | 1.27 | 7 27 |
| 1999 OQ3 | 9.1 | 0.42 | 1.90 | 20.0 | 18.5 | 19.1 | 1.48 | 7 22 |
| 1999 OP3 | 27.6 | 0.61 | 2.71 | 14.5 | 18.0 | 18.6 | 0.31 | 7 22 |
| 1999 ND43 | 5.6 | 0.31 | 1.52 | 19.1 | 19.0 | 19.1 | 0.44 | 7 14 |
| 1999 NC43 | 7.1 | 0.58 | 1.76 | 15.7 | 17.8 | 17.8 | 0.45 | 7 14 |
| 1999 NW2 | 8.7 | 0.11 | 1.12 | 23.1 | 14.8 | 15.8 | 9.38 | 7 13 |
| 1999 NC5 | 45.7 | 0.39 | 2.03 | 16.5 | 19.5 | 19.9 | 0.47 | 7 13 |
| 1999 NB5 | 1.4 | 0.53 | 2.06 | 21.6 | 19.6 | 19.7 | 0.98 | 7 13 |
| 1999 NA5 | 4.3 | 0.25 | 1.44 | 20.3 | 18.5 | 18.5 | 0.43 | 7 13 |
| 1999 LD30 | 8.7 | 0.60 | 2.90 | 20.4 | 18.3 | 18.3 | 1.50 | 6 15 |
| 1999 LQ28 | 21.8 | 0.12 | 1.20 | 19.1 | 18.1 | 18.7 | 1.09 | 6 14 |
| 1999 LP28 | 16.3 | 0.09 | 1.22 | 19.9 | 19.3 | 20.1 | 0.86 | 6 14 |
| 1999 LN28 | 9.2 | 0.47 | 2.14 | 19.3 | 17.8 | 17.7 | 0.53 | 6 12 |
| 1999 LV7 | 30.4 | 0.47 | 2.21 | 19.3 | 18.4 | 18.9 | 2.14 | 6 11 |
| 1999 LF6 | 18.9 | 0.28 | 1.41 | 18.1 | 18.3 | 19.3 | 0.85 | 6 10 |
| 1999 LE6 | 27.1 | 0.33 | 1.64 | 20.6 | 18.7 | 19.4 | 1.54 | 6 10 |
| 1999 LD6 | 11.4 | 0.49 | 1.83 | 22.4 | 19.3 | 19.7 | 4.58 | 6 10 |
| 1999 LT7 | 9.1 | 0.57 | 0.86 | 19.7 | 17.7 | 18.2 | 1.61 | 6 9 |
| 1999 LS7 | 13 | 0.30 | 1.01 | 20.6 | 16.8 | 17.2 | 3.55 | 6 8 |
| 1999 LX1 | 19.8 | 0.73 | 1.16 | 20.6 | 16.7 | 17.7 | 12.2 | 6 8 |
| 1999 LT1 | 42.6 | 0.66 | 2.98 | 17.4 | 17.8 | 18.3 | 2.68 | 6 4 |
| 1999 KX4 | 16.6 | 0.29 | 1.46 | 16.9 | 18.3 | 18.5 | 0.32 | 5 20 |
| 1999 KW4 | 38.9 | 0.69 | 0.64 | 16.7 | 16.4 | 17.3 | 2.03 | 5 20 |
| 1999 KL1 | 9.7 | 0.43 | 1.72 | 21.5 | 18.2 | 18.9 | 2.66 | 5 17 |
| 1999 KK1 | 7.1 | 0.46 | 2.12 | 18.2 | 19.1 | 19.2 | 0.40 | 5 17 |
| 1999 JZ10 | 25.9 | 0.47 | 1.31 | 21.8 | 17.9 | 18.4 | 8.00 | 5 14 |
| 1999 JA11 | 16.4 | 0.34 | 1.26 | 18.8 | 19.9 | 19.7 | 0.55 | 5 14 |
| 1999 JW6 | 51.3 | 0.14 | 1.51 | 16.8 | 17.6 | 17.9 | 1.29 | 5 13 |
| 1999 JV6 | 5.3 | 0.31 | 1.01 | 19.7 | 17.4 | 18.6 | 1.42 | 5 13 |
| 1999 JO8 | 24.7 | 0.57 | 2.66 | 17.0 | 17.1 | 16.4 | 0.31 | 5 13 |
| 1999 JM8 | 13.7 | 0.64 | 2.72 | 15.1 | 15.5 | 16.4 | 0.51 | 5 13 |
| 1999 JU6 | 22.5 | 0.20 | 1.47 | 19.3 | 17.9 | 17.9 | 1.46 | 5 12 |
| 1999 JT6 | 9.6 | 0.58 | 2.14 | 16.2 | 17.6 | 18.6 | 0.47 | 5 12 |
| 1999 JV3 | 15.2 | 0.42 | 1.45 | 19.0 | 17.3 | 17.3 | 0.95 | 5 10 |
| 1999 JU3 | 5.9 | 0.19 | 1.19 | 19.2 | 17.7 | 18.2 | 0.70 | 5 10 |
| 1999 JR6 | 17.9 | 0.64 | 1.33 | 18.6 | 19.3 | 19.1 | 0.76 | 5 10 |
| 1999 HZ1 | 8.7 | 0.58 | 1.61 | 18.2 | 18.3 | 18.3 | 0.74 | 4 20 |
| 1999 HY1 | 34.2 | 0.13 | 1.39 | 18.3 | 17.9 | 17.4 | 1.31 | 4 20 |
| 1999 HA2 | 15.1 | 0.70 | 2.79 | 17.6 | 17.7 | 18.3 | 0.66 | 4 20 |
| 1999 HX1 | 8.2 | 0.56 | 2.57 | 19.6 | 19.0 | 19.6 | 0.53 | 4 19 |
| 1999 HW1 | 23.7 | 0.46 | 2.38 | 19.8 | 19.1 | 19.6 | 1.20 | 4 19 |
| 1999 HC1 | 1.3 | 0.51 | 2.04 | 24.5 | 17.2 | 18.3 | 12.0 | 4 16 |
| 1999 GT6 | 4.3 | 0.58 | 2.83 | 17.0 | 18.4 | 18.7 | 0.35 | 4 15 |
| 1999 GS6 | 2 | 0.50 | 1.19 | 19.7 | 17.0 | 17.3 | 1.69 | 4 15 |
| 1999 GY5 | 24.5 | 0.61 | 1.15 | 19.9 | 16.3 | 17.5 | 3.02 | 4 14 |
| 1999 GL4 | 7.2 | 0.60 | 2.12 | 19.5 | 18.5 | 19.2 | 0.48 | 4 12 |
| 1999 GU3 | 12.8 | 0.51 | 2.09 | 19.6 | 13.4 | 15.2 | 9.89 | 4 10 |
| 1999 GR6 | 29.1 | 0.76 | 1.34 | 19.8 | 18.8 | 19.6 | 3.27 | 4 10 |
| 1999 GJ4 | 34.6 | 0.81 | 1.34 | 15.1 | 18.7 | 18.9 | 0.46 | 4 10 |
| 1999 GT3 | 19.5 | 0.84 | 1.34 | 17.9 | 18.0 | 18.9 | 1.71 | 4 9 |
| 1999 GJ2 | 11.3 | 0.20 | 1.54 | 16.8 | 17.5 | 17.6 | 0.46 | 4 7 |
| 1999 FK21 | 12.7 | 0.71 | 0.74 | 18.9 | 18.2 | 18.6 | 2.18 | 3 24 |
| 1999 FR19 | 20.9 | 0.48 | 1.55 | 22.3 | 17.5 | 17.2 | 7.07 | 3 23 |
| 1999 FP19 | 15.1 | 0.52 | 1.94 | 20.2 | 19.1 | 19.3 | 1.04 | 3 22 |
| 1999 FQ10 | 1.1 | 0.49 | 1.95 | 23.6 | 18.9 | 19.4 | 1.91 | 3 20 |
| 1999 FN19 | 2.3 | 0.39 | 1.65 | 22.5 | 18.7 | 19.0 | 0.25 | 3 20 |
| 1999 FR5 | 3.9 | 0.48 | 1.85 | 23.4 | 17.0 | 17.5 | 2.14 | 3 19 |
| 1999 FB | 12.9 | 0.61 | 1.18 | 17.8 | 17.3 | 17.9 | 1.31 | 3 16 |
| 1999 FA | 12 | 0.13 | 1.08 | 20.6 | 15.6 | 17.9 | 1.37 | 3 16 |
| 1999 EF5 | 31.1 | 0.43 | 2.23 | 19.8 | 18.8 | 19.6 | 1.56 | 3 15 |
| 1999 EE5 | 31 | 0.28 | 1.67 | 18.5 | 16.8 | 18.1 | 2.27 | 3 15 |
| 1999 DB7 | 10.8 | 0.20 | 1.21 | 19.9 | 15.7 | 16.7 | 6.39 | 2 26 |
| 1999 DJ4 | 9.2 | 0.48 | 1.85 | 18.2 | 16.8 | 17.6 | 1.67 | 2 24 |
| 1999 DY2 | 7.6 | 0.46 | 2.04 | 21.9 | 18.8 | 19.4 | 1.27 | 2 18 |
| 1999 DK3 | 43.1 | 0.44 | 2.12 | 17.3 | 18.8 | 19.9 | 0.92 | 2 18 |
| 1999 DB2 | 11.6 | 0.62 | 3.00 | 19.1 | 19.1 | 19.4 | 0.41 | 2 16 |
| 1999 CW8 | 33.7 | 0.60 | 2.24 | 18.5 | 17.4 | 18.0 | 1.98 | 2 12 |
| 1999 CF9 | 5.5 | 0.60 | 1.77 | 17.9 | 16.7 | 18.2 | 0.70 | 2 12 |
| 1999 CV8 | 15.3 | 0.35 | 1.30 | 19.6 | 17.9 | 18.9 | 1.24 | 2 11 |
| 1999 CV3 | 22.9 | 0.39 | 1.46 | 15.0 | 19.3 | 19.3 | 1.36 | 2 10 |
| 1999 CU3 | 11.4 | 0.52 | 1.58 | 16.9 | 18.7 | 19.3 | 0.51 | 2 10 |
| 1999 CT3 | 34.2 | 0.13 | 1.43 | 18.0 | 18.3 | 19.0 | 1.14 | 2 10 |
| 1999 CG9 | 5.2 | 0.06 | 1.06 | 25.2 | 17.8 | 19.2 | 3.26 | 2 10 |
| 1999 CT8 | 44.5 | 0.39 | 1.25 | 18.3 | 18.6 | 19.5 | 1.75 | 2 9 |
| 1999 BO | 19.6 | 0.45 | 2.12 | 18.4 | 17.4 | 18.7 | 1.10 | 1 16 |
| 1999 AQ10 | 6.6 | 0.23 | 0.94 | 20.4 | 17.7 | 18.6 | 1.03 | 1 14 |
| 1999 AP10 | 7.6 | 0.58 | 2.38 | 16.5 | 15.8 | 18.1 | 0.69 | 1 14 |
| 1999 AO10 | 2.6 | 0.11 | 0.91 | 23.9 | 17.7 | 18.0 | 4.14 | 1 13 |
| 1999 AN10 | 39.9 | 0.56 | 1.46 | 18.0 | 18.3 | 18.9 | 0.82 | 1 13 |
| 1999 AM10 | 6.9 | 0.52 | 1.82 | 21.0 | 17.8 | 18.7 | 3.59 | 1 13 |
| 1999 AR7 | 40.6 | 0.21 | 1.64 | 16.5 | 18.2 | 19.1 | 0.83 | 1 11 |
| 1999 AU23 | 20.4 | 0.41 | 2.16 | 17.2 | 18.3 | 19.3 | 0.98 | 1 9 |
| 1999 AF4 | 12.6 | 0.62 | 2.83 | 18.2 | 16.9 | 17.9 | 1.90 | 1 9 |
| 1998 Discoveries | | | | | | | | |
| 1998 YP11 | 15 | 0.39 | 1.72 | 16.3 | 16.6 | 19.2 | 0.55 | 12 23 |
| 1998 YR11 | 59.7 | 0.48 | 2.03 | 18.1 | 18.5 | 19.0 | 2.33 | 12 23 |
| 1998 YQ11 | 11.9 | 0.40 | 1.87 | 18.0 | 19.0 | 18.9 | 1.16 | 12 23 |
| 1998 YB8 | 8.9 | 0.47 | 2.42 | 18.9 | 17.8 | 18.4 | 0.51 | 12 22 |
| 1998 YW5 | 8.5 | 0.63 | 1.25 | 19.6 | 18.7 | 19.9 | 1.45 | 12 19 |
| 1998 YW3 | 28.8 | 0.46 | 1.10 | 17.9 | 18.8 | 19.3 | 0.84 | 12 17 |
| 1998 YO4 | 9.3 | 0.25 | 1.65 | 16.2 | 18.6 | 19.2 | 0.32 | 12 17 |
| 1998 YN1 | 6.3 | 0.47 | 1.56 | 17.8 | 18.4 | 18.8 | 0.52 | 12 16 |
| 1998 XS16 | 26.6 | 0.50 | 1.21 | 16.3 | 18.1 | 19.0 | 0.61 | 12 15 |
| 1998 XR16 | 20.6 | 0.58 | 2.27 | 18.6 | 17.5 | 17.8 | 0.90 | 12 15 |
| 1998 XN17 | 7.2 | 0.21 | 0.98 | 22.4 | 18.4 | 18.9 | 1.87 | 12 15 |
| 1998 XE12 | 13.4 | 0.74 | 0.88 | 18.9 | 18.5 | 19.7 | 1.30 | 12 14 |
| 1998 XD12 | 13.5 | 0.62 | 1.40 | 20.3 | 16.8 | 18.0 | 1.86 | 12 14 |
| 1998 XA5 | 31.8 | 0.31 | 1.56 | 18.8 | 17.3 | 17.8 | 1.64 | 12 12 |
| 1998 XC9 | 9.3 | 0.53 | 2.75 | 18.1 | 17.7 | 18.8 | 0.29 | 12 12 |
| 1998 XZ4 | 23.2 | 0.64 | 1.94 | 16.3 | 17.8 | 18.7 | 0.66 | 12 11 |
| 1998 XM4 | 62.7 | 0.42 | 1.66 | 14.9 | 18.1 | 17.9 | 0.66 | 12 10 |
| 1998 XN2 | 1.8 | 0.54 | 2.00 | 19.5 | 16.6 | 17.7 | 3.93 | 12 9 |

*Note.* Incl, orbital elements inclination; *e*, eccentricity; *a*, semimajor axis; and *H*, absolute magnitude—all derived by Minor Planet Center (Minor Planet Center 2000). V magnitude, visual magnitude obtained by propagating absolute visual magnitude to date of discovery; L magnitude, LINEAR's observed magnitude reported to MPC at time of discovery; vel, velocity, apparent motion measured in degrees/day at time of discovery.

**TABLE AI**—*Continued*

| Provisional Designation | Incl (deg) | e | a (au) | H | V mag | L mag | vel | Disc date |
|---|---|---|---|---|---|---|---|---|
| 1998 XM2 | 27.1 | 0.34 | 1.81 | 17.2 | 18.6 | 19.2 | 1.00 | 12 9 |
| 1998 XX2 | 6.9 | 0.37 | 0.74 | 20.1 | 18.4 | 19.1 | 1.50 | 12 8 |
| 1998 WT24 | 7.4 | 0.42 | 0.72 | 17.7 | 17.8 | 18.1 | 1.14 | 11 25 |
| 1998 WT7 | 40.7 | 0.11 | 1.15 | 18.5 | 17.7 | 17.8 | 3.22 | 11 23 |
| 1998 WR5 | 28.1 | 0.52 | 2.58 | 18.0 | 18.0 | 19.2 | 1.25 | 11 19 |
| 1998 WQ5 | 27.7 | 0.36 | 1.72 | 15.3 | 18.0 | 19.4 | 0.36 | 11 19 |
| 1998 WP5 | 19.5 | 0.20 | 1.37 | 18.7 | 18.0 | 18.9 | 1.20 | 11 19 |
| 1998 WB2 | 2.4 | 0.59 | 1.98 | 21.8 | 18.1 | 18.6 | 0.39 | 11 18 |
| 1998 WA2 | 22.4 | 0.60 | 2.71 | 19.2 | 17.4 | 18.3 | 1.24 | 11 18 |
| 1998 WZ1 | 4.3 | 0.56 | 2.16 | 19.9 | 18.5 | 19.4 | 1.11 | 11 16 |
| 1998 WY1 | 24.7 | 0.36 | 1.62 | 21.8 | 17.8 | 18.6 | 6.08 | 11 16 |
| 1998 WT | 3.2 | 0.57 | 1.22 | 17.5 | 17.2 | 18.7 | 0.43 | 11 16 |
| 1998 WM | 22.5 | 0.32 | 1.23 | 16.7 | 17.5 | 18.5 | 0.73 | 11 16 |
| 1998 VF32 | 24 | 0.45 | 0.85 | 21.1 | 17.2 | 18.5 | 3.01 | 11 14 |
| 1998 VD32 | 2 | 0.31 | 1.10 | 22.2 | 17.9 | 18.2 | 2.15 | 11 14 |
| 1998 VE31 | 21.9 | 0.19 | 1.05 | 20.7 | 18.2 | 18.7 | 2.25 | 11 13 |
| 1998 VS | 6.8 | 0.28 | 1.40 | 21.9 | 17.1 | 18.1 | 2.22 | 11 10 |
| 1998 VR | 21.8 | 0.32 | 0.88 | 18.5 | 15.3 | 16.4 | 2.66 | 11 10 |
| 1998 VP | 43.9 | 0.46 | 1.88 | 18.9 | 17.7 | 18.1 | 1.87 | 11 10 |
| 1998 VO | 10.1 | 0.23 | 1.07 | 20.4 | 15.7 | 17.8 | 2.19 | 11 10 |
| 1998 VN | 12 | 0.35 | 1.39 | 20.5 | 16.8 | 17.4 | 2.07 | 11 10 |
| 1998 UY24 | 16.9 | 0.32 | 1.36 | 21.6 | 18.6 | 19.2 | 1.86 | 10 29 |
| 1998 UO1 | 25.6 | 0.76 | 1.60 | 16.4 | 17.6 | 18.5 | 0.85 | 10 19 |
| 1998 UN1 | 32.4 | 0.22 | 1.51 | 18.2 | 18.1 | 18.9 | 1.37 | 10 19 |
| 1998 UM1 | 4.8 | 0.40 | 1.69 | 23.0 | 18.2 | 19.3 | 2.75 | 10 19 |
| 1998 UP1 | 33.2 | 0.35 | 1.00 | 20.3 | 17.6 | 18.7 | 2.56 | 10 18 |
| 1998 UL1 | 42 | 0.21 | 1.53 | 16.5 | 18.2 | 19.0 | 0.76 | 10 18 |
| 1998 UR | 17.3 | 0.38 | 1.64 | 23.0 | 19.3 | 19.4 | 3.26 | 10 16 |
| 1998 TU3 | 5.4 | 0.48 | 0.79 | 15.0 | 16.1 | 16.4 | 0.87 | 10 13 |
| 1998 ST49 | 24.6 | 0.59 | 2.31 | 17.7 | 16.9 | 18.0 | 3.10 | 9 29 |
| 1998 SS49 | 10.8 | 0.64 | 1.92 | 15.9 | 17.6 | 18.6 | 0.67 | 9 29 |
| 1998 SR49 | 29.2 | 0.54 | 2.48 | 17.2 | 18.2 | 19.1 | 1.33 | 9 29 |
| 1998 SH36 | 2.1 | 0.57 | 1.09 | 20.5 | 17.8 | 18.5 | 0.26 | 9 27 |
| 1998 SJ70 | 7.4 | 0.71 | 2.23 | 18.5 | 17.9 | 18.5 | 1.17 | 9 26 |
| 1998 SG36 | 24.9 | 0.34 | 1.65 | 16.2 | 18.8 | 19.3 | 0.45 | 9 26 |
| 1998 SF36 | 1.7 | 0.28 | 1.33 | 18.8 | 18.6 | 19.4 | 0.58 | 9 26 |
| 1998 SE36 | 11.7 | 0.10 | 1.34 | 19.5 | 19.1 | 19.6 | 0.62 | 9 26 |
| 1998 SU27 | 7.1 | 0.59 | 2.13 | 19.2 | 18.0 | 19.3 | 0.97 | 9 24 |
| 1998 ST27 | 21 | 0.53 | 0.82 | 19.5 | 18.2 | 19.5 | 1.88 | 9 24 |
| 1998 SF35 | 35.2 | 0.27 | 1.69 | 17.5 | 19.4 | 20.0 | 0.36 | 9 24 |
| 1998 SE35 | 14.8 | 0.60 | 3.00 | 18.9 | 18.1 | 18.8 | 1.11 | 9 24 |
| 1998 SD15 | 26.8 | 0.35 | 0.93 | 19.0 | 15.7 | 18.4 | 4.37 | 9 23 |
| 1998 SC15 | 16.1 | 0.42 | 1.27 | 19.4 | 18.9 | 19.8 | 0.91 | 9 23 |
| 1998 SZ27 | 23.4 | 0.50 | 0.90 | 20.5 | 18.1 | 18.8 | 1.02 | 9 21 |
| 1998 SZ14 | 5.6 | 0.48 | 2.39 | 19.0 | 17.8 | 18.8 | 0.41 | 9 21 |
| 1998 SY14 | 3.5 | 0.67 | 2.85 | 20.6 | 19.6 | 19.7 | 0.46 | 9 21 |
| 1998 SB15 | 15.6 | 0.16 | 1.23 | 20.8 | 18.0 | 19.0 | 1.52 | 9 21 |
| 1998 SA15 | 7.1 | 0.56 | 1.92 | 19.7 | 19.2 | 19.3 | 0.74 | 9 21 |
| 1998 SV4 | 53.3 | 0.64 | 0.82 | 18.5 | 17.6 | 18.3 | 2.36 | 9 19 |
| 1998 SU4 | 23.4 | 0.58 | 1.16 | 21.0 | 17.6 | 18.5 | 2.27 | 9 19 |
| 1998 RO4 | 5.3 | 0.43 | 2.14 | 17.9 | 17.5 | 18.3 | 0.32 | 9 14 |
| 1998 RO1 | 22.7 | 0.72 | 0.99 | 18.1 | 17.9 | 18.3 | 1.41 | 9 14 |
| 1998 RN1 | 26.8 | 0.59 | 2.61 | 19.0 | 17.8 | 18.0 | 1.29 | 9 14 |
| 1998 QQ63 | 1.7 | 0.55 | 2.37 | 18.7 | 18.8 | 19.6 | 1.37 | 8 31 |
| 1998 QA62 | 24.9 | 0.75 | 2.08 | 18.5 | 18.3 | 19.5 | 1.73 | 8 29 |
| 1998 QK56 | 13.5 | 0.51 | 1.88 | 17.5 | 19.3 | 17.8 | 0.62 | 8 28 |
| 1998 QR52 | 17.6 | 0.29 | 1.04 | 18.7 | 18.6 | 19.1 | 0.88 | 8 27 |
| 1998 QQ52 | 4.8 | 0.46 | 2.10 | 21.0 | 18.7 | 19.3 | 0.94 | 8 27 |
| 1998 QS52 | 17.7 | 0.86 | 2.20 | 14.3 | 18.4 | 19.4 | 0.34 | 8 25 |
| 1998 QK28 | 7.7 | 0.56 | 2.23 | 19.5 | 16.3 | 17.8 | 2.09 | 8 25 |
| 1998 QR15 | 9.7 | 0.57 | 2.76 | 18.0 | 16.7 | 18.0 | 0.58 | 8 23 |
| 1998 QE2 | 12.7 | 0.57 | 2.44 | 16.5 | 18.8 | 19.2 | 0.38 | 8 19 |
| 1998 QA1 | 8.2 | 0.53 | 2.10 | 18.7 | 16.9 | 18.4 | 0.44 | 8 19 |
| 1998 QV3 | 14.3 | 0.51 | 2.32 | 20.5 | 18.7 | 18.9 | 1.19 | 8 17 |
| 1998 QQ | 36.7 | 0.68 | 1.23 | 19.0 | 18.0 | 18.2 | 1.77 | 8 17 |
| 1998 QP | 9.4 | 0.59 | 1.79 | 21.5 | 16.3 | 17.6 | 1.62 | 8 17 |
| 1998 QH1 | 12.4 | 0.55 | 2.54 | 20.5 | 19.7 | 19.7 | 0.74 | 8 17 |
| 1998 QC1 | 9.6 | 0.59 | 1.98 | 19.6 | 18.9 | 19.3 | 0.66 | 8 17 |
| 1998 PB1 | 6 | 0.43 | 2.03 | 17.3 | 15.8 | 17.0 | 1.05 | 8 15 |
| 1998 OK1 | 13.9 | 0.42 | 1.35 | 19.5 | 16.3 | 18.4 | 1.09 | 7 21 |
| 1998 MR24 | 6.1 | 0.45 | 1.96 | 19.0 | 17.4 | 18.1 | 1.62 | 6 30 |
| 1998 MT24 | 34 | 0.65 | 2.42 | 14.7 | 17.6 | 17.9 | 0.39 | 6 29 |
| 1998 MN14 | 19.5 | 0.22 | 1.56 | 17.8 | 16.1 | 18.1 | 1.19 | 6 25 |
| 1998 MX5 | 9.7 | 0.61 | 2.92 | 18.1 | 16.5 | 17.4 | 0.76 | 6 24 |
| 1998 MW5 | 6.3 | 0.36 | 1.02 | 19.2 | 18.4 | 18.2 | 0.68 | 6 24 |
| 1998 ML14 | 2.5 | 0.62 | 2.42 | 17.6 | 16.9 | 16.9 | 0.11 | 6 24 |
| 1998 MV5 | 21.1 | 0.19 | 1.20 | 24.0 | 17.3 | 18.3 | 9.44 | 6 23 |
| 1998 ME3 | 6 | 0.48 | 2.18 | 19.5 | 17.6 | 17.2 | 0.23 | 6 19 |
| 1998 LE | 9.1 | 0.70 | 1.52 | 20.5 | 17.2 | 17.7 | 4.47 | 6 4 |
| 1998 LD | 22.5 | 0.17 | 1.44 | 20.5 | 18.0 | 18.3 | 1.92 | 6 3 |
| 1998 KK17 | 11.1 | 0.52 | 1.43 | 16.4 | 17.3 | 17.7 | 0.87 | 5 29 |
| 1998 KJ17 | 9.2 | 0.48 | 1.99 | 23.5 | 18.2 | 18.8 | 7.48 | 5 28 |
| 1998 KJ9 | 11 | 0.64 | 1.45 | 19.5 | 17.5 | 18.0 | 2.08 | 5 27 |
| 1998 KH9 | 17.7 | 0.46 | 2.20 | 18.5 | 17.5 | 18.2 | 0.86 | 5 27 |
| 1998 KO3 | 54.5 | 0.77 | 2.60 | 19.3 | 17.5 | 18.0 | 3.54 | 5 24 |
| 1998 KN3 | 2.4 | 0.89 | 1.61 | 18.5 | 17.5 | 19.0 | 1.59 | 5 24 |
| 1998 KM3 | 4.7 | 0.62 | 1.69 | 19.5 | 17.5 | 19.7 | 0.98 | 5 24 |
| 1998 KD3 | 29.2 | 0.51 | 2.05 | 21.0 | 18.5 | 15.9 | 9.23 | 5 24 |
| 1998 KF3 | 27.1 | 0.42 | 2.13 | 19.0 | 18.5 | 19.1 | 0.93 | 5 23 |
| 1998 KV2 | 13 | 0.33 | 1.59 | 17.4 | 18.7 | 18.8 | 0.50 | 5 22 |
| 1998 KU2 | 4.9 | 0.55 | 2.25 | 16.6 | 17.0 | 18.2 | 0.47 | 5 22 |
| 1998 KH | 26.3 | 0.71 | 1.65 | 18.4 | 17.5 | 18.2 | 0.00 | 5 16 |
| 1998 HJ41 | 38.9 | 0.13 | 1.36 | 18.0 | 18.1 | 18.6 | 1.49 | 4 28 |
| 1998 HM3 | 39.3 | 0.06 | 1.25 | 18.5 | 17.0 | 18.0 | 2.15 | 4 21 |
| 1998 HL3 | 2.7 | 0.37 | 1.13 | 20.0 | 18.9 | 19.8 | 0.76 | 4 21 |
| 1998 HK3 | 24.7 | 0.30 | 1.83 | 17.5 | 18.9 | 19.8 | 0.59 | 4 20 |
| 1998 HJ3 | 6.5 | 0.74 | 1.99 | 18.5 | 18.9 | 19.7 | 1.08 | 4 19 |
| 1998 HL1 | 20 | 0.19 | 1.25 | 19.0 | 18.8 | 19.6 | 0.84 | 4 18 |
| 1998 HK1 | 8 | 0.43 | 2.16 | 19.5 | 18.1 | 19.0 | 0.42 | 4 18 |
| 1998 GL10 | 8.7 | 0.67 | 3.18 | 18.0 | 18.7 | 19.5 | 0.64 | 4 15 |
| 1998 GC1 | 18.8 | 0.29 | 1.44 | 21.0 | 18.7 | 19.0 | 2.74 | 4 2 |
| 1998 FJ74 | 28.2 | 0.54 | 2.41 | 18.5 | 18.5 | 19.1 | 1.05 | 3 31 |
| 1998 FH74 | 21.4 | 0.88 | 2.19 | 15.5 | 18.9 | 18.8 | 0.50 | 3 31 |
| 1998 FH12 | 3.5 | 0.54 | 1.09 | 19.0 | 18.7 | 19.4 | 0.54 | 3 25 |
| 1998 FR11 | 6.6 | 0.71 | 2.80 | 16.5 | 19.3 | 19.5 | 0.41 | 3 24 |
| 1998 FN9 | 14.6 | 0.24 | 1.40 | 21.0 | 18.0 | 19.2 | 1.99 | 3 24 |
| 1998 FM9 | 10.4 | 0.44 | 2.29 | 19.5 | 18.4 | 19.0 | 0.58 | 3 24 |
| 1998 FG12 | 8.6 | 0.58 | 2.24 | 21.0 | 18.9 | 19.4 | 1.11 | 3 24 |
| 1998 FF14 | 38 | 0.31 | 1.24 | 20.5 | 18.9 | 19.9 | 1.93 | 3 24 |
| 1998 FX2 | 10 | 0.49 | 2.15 | 18.3 | 14.3 | 17.5 | 1.98 | 3 22 |
| 1998 FL5 | 14.5 | 0.37 | 1.55 | 21.5 | 18.8 | 19.2 | 1.77 | 3 22 |
| 1998 FW4 | 3.6 | 0.73 | 2.50 | 19.0 | 18.5 | 19.4 | 0.76 | 3 20 |
| 1998 FF2 | 11 | 0.29 | 1.56 | 18.9 | 18.3 | 18.7 | 0.57 | 3 20 |
| 1998FX134 | 5.2 | 0.43 | 2.26 | 18.5 | 18.5 | 19.3 | 0.26 | 3 20 |
| 1997 Discoveries | | | | | | | | |
| 1997 XS2 | 19.6 | 0.52 | 2.65 | 19.5 | 18.3 | 18.8 | 1.02 | 12 4 |
| 1997 XR2 | 7.2 | 0.20 | 1.08 | 21.0 | 17.4 | 17.3 | 1.74 | 12 4 |
| 1997 XE10 | 6.3 | 0.48 | 1.87 | 25.0 | 17.4 | 18.8 | 9.15 | 12 4 |
| 1997 WT22 | 8.2 | 0.31 | 1.49 | 19.0 | 17.9 | 19.1 | 0.64 | 11 29 |
| 1997WQ23 | 2.5 | 0.50 | 1.74 | 20.5 | 18.1 | 18.5 | 0.68 | 11 29 |
| 1997 VG6 | 18.5 | 0.56 | 1.61 | 19.5 | 18.1 | 19.3 | 1.46 | 11 7 |
| 1997 VN4 | 7.6 | 0.56 | 2.44 | 23.5 | 17.9 | 19.6 | 2.68 | 11 6 |
| 1997 VM4 | 14.1 | 0.81 | 2.62 | 18.0 | 18.6 | 19.4 | 0.70 | 11 6 |
| 1997 VG | 31 | 0.40 | 1.75 | 22.0 | 17.9 | 0.0 | 6.71 | 11 1 |
| 1997 US9 | 20 | 0.28 | 1.05 | 17.3 | 16.3 | 0.0 | 1.11 | 10 30 |
| 1997 UZ10 | 12.7 | 0.62 | 2.86 | 23.0 | 17.9 | 20.1 | 3.07 | 10 29 |
| 1997 UF9 | 25.9 | 0.60 | 1.44 | 16.2 | 18.2 | 18.9 | 0.60 | 10 29 |
| 1997 UA11 | 3.3 | 0.62 | 2.38 | 25.0 | 18.6 | 19.6 | 0.00 | 10 29 |
| 1997 UR | 2.3 | 0.31 | 1.46 | 23.0 | 16.6 | 18.1 | 0.00 | 10 22 |
| 1997 MS | 55 | 0.73 | 1.94 | 19.0 | 18.2 | #N/A | #N/A | 6 25 |
| 1997 JC | 15 | 0.30 | 1.74 | 19.0 | 16.6 | #N/A | #N/A | 5 1 |
| 1997 GC32 | 5.9 | 0.66 | 2.03 | 18.5 | 19.3 | #N/A | #N/A | 4 14 |
| 1997 GL3 | 6.7 | 0.78 | 2.28 | 20.0 | 19.3 | #N/A | #N/A | 4 7 |

### TABLE AII
### Unusual Objects Discovered by LINEAR through September 1999

| Provisional designation | $H$ | Incl (deg) | $e$ | $a$ (au) | Discovery date |
|---|---|---|---|---|---|
| 1999 SD10 | 17.2 | 6 | 0.536 | 3.083 | 1999 9 30 |
| 1999 SK5 | 18.2 | 47 | 0.42 | 2.451 | 1999 9 30 |
| 1999 LE31 | 12.4 | 151.9 | 0.472 | 8.163 | 1999 6 12 |
| 1999 LD31 | 13.5 | 160.2 | 0.903 | 24.42 | 1999 6 8 |
| 1999 HX2 | 15.2 | 16.5 | 0.555 | 3.179 | 1999 4 22 |
| 1998 WU24 | 15 | 42.6 | 0.907 | 15.179 | 1998 11 25 |
| 1998 UQ1 | 16.5 | 64.5 | 0.52 | 3.199 | 1998 10 19 |
| 1998 QJ1 | 16.5 | 23.4 | 0.815 | 11.444 | 1998 8 17 |
| 1998 KK56 | 16.5 | 25.7 | 0.514 | 3.169 | 1998 5 27 |
| 1998 HU108 | 17 | 9.3 | 0.509 | 2.752 | 1998 4 23 |
| 1997 MD10 | 16 | 59.1 | 0.943 | 26.965 | 1997 6 29 |

### TABLE AIII
### Comets Discovered by LINEAR through September 1999

| Month of discovery | No. | Designation |
|---|---|---|
| March 1998 | 0 | |
| April 1998 | 1 | C/1998 G1 |
| May 1998 | 3 | C/1998 K2, C/1998 K3, C/1998 K5, |
| June 1998 | 4 | C/1998 M1, C/1998 M2, C/1998 M4, C/1998 M5, |
| July 1998 | 0 | |
| August 1998 | 1 | C/1998 Q1 |
| September 1998 | 1 | P/1998 S1[a] |
| October 1998 | 3 | C/1998 T1, C/1998 U1, C/1998 U5 |
| November 1998 | 2 | P/1998 VS24, C/1998 W3 |
| December 1998 | 1 | C/1998 Y1 |
| January 1999 | 0 | |
| February 1999 | 0 | |
| March 1999 | 0 | |
| April 1999 | 2 | C/1999 G1, C/1999 H3 |
| May 1999 | 9 | C/1999 J3, C/1999 J4, P/1999 J5, C/1999 K3, C/1999 K4, C/1999 K5, C/1999 K6, C/1999 K6, C/1999 K8 |
| June 1999 | 2 | C/1999 L2, C/1999 L3 |
| July 1999 | 1 | C/1999 N4 |
| August 1999 | 0 | |
| September 1999 | 2 | C/1999 S3, C/1999 S4 |

[a] P/1998 S1 discovered by LINEAR-Mueller.

by LINEAR through September 1999. Of LINEAR's discovered NEAs, 64 are currently listed as PHAs (potentially hazardous asteroids). The LINEAR NEA population breaks down as follows: 19 Atens, 115 Amors, and 123 Apollos.

Through September 1999:

| | |
|---|---|
| Total known NEAs | 797 (367 Amors, 55 Atens, 375 Apollos) |
| LINEAR NEAs | 257 (115 Amors, 19 Atens, 123 Apollos) |
| Total PHAs | 196 |
| LINEAR PHAs | 64 |
| Total unusual | 44 |
| LINEAR unusual | 11 |
| NEAs $>$ 1 km | 323 ($H \leq 18.0$) |
| LINEAR NEAs $>$ 1 km | 72 ($H \leq 18.0$) |
| LINEAR comets | 32 |

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