Near-Earth Asteroid Tracking (NEAT) Program

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ABSTRACT: The discoveries of near-Earth asteroids (NEAs) and comets have increased enormously over the last 10-20 years. This is a consequence, in large part, of the success of programs that have systematically searched for these objects. These programs have been motivated by the relationships of NEAs to terrestrial impacts, meteorites, comets, and their relative accessibility to spacecraft missions. This paper will review the long-term Palomar Planet-Crossing Asteroid Survey (PCAS), a photographic program, and the current Near-Earth Asteroid Tracking (NEAT) system, NASA's new electronic detection program. The primary goal of NEAT is to discover and inventory near-Earth asteroids and comets, collectively called near-Earth objects or NEOs, larger than 1 km in size. Details of the NEAT system and program results are presented and discussed.

HISTORICAL BACKGROUND

The predecessor to the Near-Earth Asteroid Tracking (NEAT) program was the Palomar Planet-Crossing Asteroid Survey (PCAS) [5], [6] a photographic program conducted at Palomar Observatory using the 0.46 m Schmidt telescope. It was the first and longest running program dedicated to the detection of NEOS. It was discontinued in June 1995, after 23 years of operation.

The dedicated, systematic PCAS program searched the sky six nights monthly, typically covering about 4,000 square degrees of sky, each observing run centered near opposition and along the ecliptic. This coverage led to the discovery of 1 to 2 NEOS each month. Each exposure taken with this wide-angle telescope covers about eight degrees of sky in diameter or about 60 square degrees, almost the size of the bowl of the Big Dipper. The venerable old Schmidt camera telescope is a fast photographic system (focal ratio of 2). Film pairs of preselected centers (standard fields) were taken during the search program producing important discoveries and an extensive archive of films.

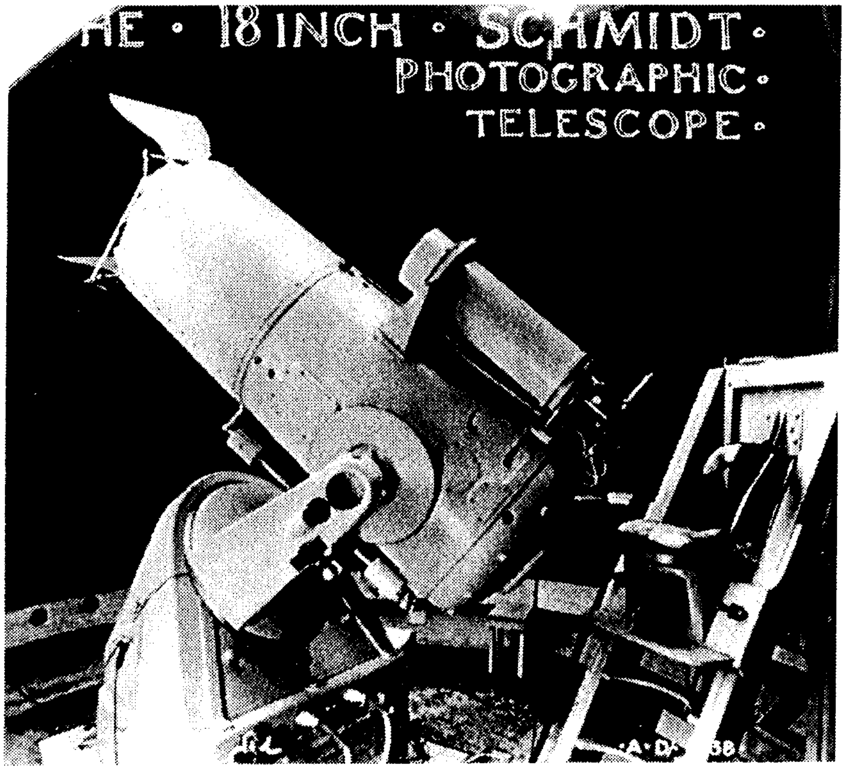

FIGURE 1. For over 60 years the Palomar 0.46 m (18-inch) telescope has been operational. It resembles a large mortar cannon ready for firing and has been responsible for two-thirds of the near-Earth asteroids that have been found in the last 20 years before electronic search systems became active.

METHODS AND PROCEDURES USED DURING THE PROGRAM

Methods used were standardized as soon as the system was working satisfactorily given the constraints of the telescope and photographic material available. The observing part of the program remained essentially the same in terms of acquiring the data. Eight films, or four pairs of films, were exposed for 8–10 minutes and then developed. Film pairs were exposed at the same position in the sky separated by approximately 30 minutes in time. Once the films were dry, they were scanned on a custom-designed stereomicroscope. This inspection was done promptly so discoveries could be made close to real time and new, fast-moving objects (fmo) could bc followed up the same night if possible. These additional observations were acquired as quickly as possible in order to assure sufficient positions to determine a preliminary orbit (for example, the independent discovery of the bright asteroid Toutatis).

With the introduction of improved Kodak 4415 film, and new hypersensitization procedures, it was possible to reduce the exposure time to 6 minutes. The shorter exposure time allowed more photographs to be acquired resulting in greater sky coverage, With the "hypered" film and optimum exposure time, we were able to extend the limiting magnitude to approximately 18.5 for stellar objects. With greater sky coverage and limiting magnitude, the PCAS discovery rate increased, achieving the primary objective of our search program and maximizing the discovery of NEOs.

The typical observing team was comprised of three, sometimes four members alternating tasks throughout the night. Telescope activities included the telescope observing, developing film, scanning and inspection of films, labeling films, interacting with the Minor Planet Center and other observers via e-mail. During the first few hours of the night, fields for follow-up observations were taken. Usually, this was for objects recently discovered on prior observing runs. As soon as two hours postopposition was high enough in the sky, we concentrated heavily upon the anti-Sun or opposition area of the sky for the majority of the night. Our main concentration was from two hours pre- through postopposition and along the ecliptic. In addition, we always tried to obtain follow-up fields on a second night two or three nights later in the run. This would allow for confirmatory positions of any new objects discovered.

RESULTS FROM THE SYSTEMATIC PHOTOGRAPHIC SURVEY: PCAS

Overall, PCAS' contributions to the scientific community have been substantial and multifaceted: a total of 95 NEA discoveries (plus many independent discoveries), 17 comets, plus dozens of crucial confirmatory and prediscovery observations. Also, PCAS was instrumental in attracting worldwide NEO participation through its on-going program.

The majority of NEOS in the last twenty years have been discovered with wide-field photographic Schmidt telescopes. This growing number of discoveries gained the attention of the scientific community and in time, sparked the interest of the press and other media. From the small Schmidt telescope at Palomar Observatory the long-term PCAS program had been productive in the discovery of a significant number of the NEOS.

SOME NOTABLE PCAS DISCOVERIES

The first NEA discovered was 54961973 NA, a rapidly moving asteroid found on the July 4, 1973. It was a bright object (magnitude 10–11) moving

11° per day into the southern hemisphere. It has a very high inclination of 68°, still holding the record for highest inclination among the known NEAs. It is probably a degassed comet.

2062 Aten, the first asteroid with an orbit smaller than the Earth's, was found January 7, 1976. It became the prototype of a new class of rare asteroids which, because of their small orbits, never venture far from the orbit of the Earth. Ultimately, these asteroids with relatively short dynamical lifetimes have a high potential for colliding with the Earth [4].

In 1979, a bright asteroid, 4015 1979 VA, was found moving in a cometary-like orbit [6]. This asteroid, 1979 VA, was later linked with an image photographed in 1949 during the Palomar Observatory Sky Survey. In the 1949 photo, it had a "tail," providing evidence that 30 years prior to its discovery as an asteroidal object, it was a comet with a tail [1]. This was the first direct proof of a comet evolving into an asteroid after its supply of ices and volatiles *were* depleted. As the discoverer, Helin had not yet named the numbered asteroid when it was linked to comet 107P/Wilson-Barrington. Henceforth, it was called by that name. A numbered asteroid with a comet name, P/107 Wilson-Barrington = 4015 1979VA [2].

Several asteroids, 37571982 XB, 6489 Golevka, 1989 ML are excellent candidates for spacecraft missions because of the low-energy expenditures required for rendezvous. In 1996, 6489 Golevka was imaged by radar (from Goldstone in the US, Evpatoria in Russia, and Kashima in Japan) greatly refining its orbit/ephemeris for future mission consideration [14].

BACKGROUND ON THE UNITED STATES AIR FORCE "GROUND-BASED ELECTRO-OPTICAL DEEP SPACE SURVEILLANCE SYSTEM (GEODSS)

The GEODSS satellite surveillance system has been in existence since the early 1980s. They utilize two "main" telescopes of 1 m aperture and one auxilary telescope, a 0.35 m (14-inch) folded Schmidt, at each site distributed around the globe. GEODSS sites provide "deep" space surveillance in detecting, tracking, and identifying manmade objects. This network of telescopes have always been attractive to astronomers. Discussions began in midsummer of 1992 to explore the possibility of using the 1 m telescope by placing a state-of-the-art charge-coupled device (CCD) camera at the focal plane, fully utilizing the large-field of view of their instrument. Some observing time became available in the aftermath of the Cold War and consideration was given to using this powerful, fast detection system for natural near-Earth objects. This collaboration was formalized and the NEAT program began in December 1995. It has served as an unparalleled opportunity for NASA/JPL to collaborate with the Air Force in searching for NEAs. A highly successful detection program has been developed using a military telescope for scientific purposes, producing a economical and efficient system through an innovative and mutually beneficial partnership.

THE NEAR-EARTH ASTEROID TRACKING (NEAT) PROGRAM

Introduction

The Near-Earth Asteroid Tracking (NEAT) program is an autonomous observational system located at the United States Air Force/Ground-based Electro-Optical Deep Space Surveillance (GEODSS) site on Haleakala, Maui, Hawaii. It is a cooperative effort between the National Aeronautics and Space Administration/Jet Propulsion Laboratory and the United States Air Force. It is an innovative detection system using a charge-coupled device (CCD) system and pattern recognition software and has been in operation since December, 1995. It is the first fully-automated detection program, operated remotely without JPL personnel on site. For the first year, NEAT observations were scheduled for a 12-night period centered near the new moon. Beginning in January 1997, NEAT began observing the 6 nights prior to the new moon each month. An observing script, consisting of a list of software instructions, is transmitted to a JPL Spare Station computer located at the GEODSS facility each afternoon. The observations are taken as scheduled through the night until morning twilight. The NEAT observing file is "clicked" off at dawn and the software-identified images/observations are transmitted to JPL. The detection data are in the form of small snap shot images (patches) which are visually inspected. Shortly thereafter, 3 positions of each object are electronically mailed to the Smithsonian Astrophysical Observatory (Minor Planet Center) for recording, identification, and designation. This program has now produced over 10,000 detections, 5637 new asteroids, 886 new designations. NEAT has discovered 14 near-Earth asteroids, 5 Earth-crossers including 1 Aten, 8 Earth-approachers; (see Table of Significant Discoveries), 2 long-period comets, and the unique asteroid, 1996 PW, which moves in a comet-like orbit and has the highest eccentricity known for an asteroid. In addition, dozens of high inclination asteroids and numerous Mars-crossers have been found.

Purpose

The fundamental goal of the NEAT program is to significantly increase the known population of NEOS to limiting magnitude 20.0 with the current CCD/telescope system. It was designed to complete a comprehensive search of the sky for near-Earth asteroids and comets, collectively called near-Earth objects or NEOS, as defined within the Spaceguard Survey report. This forms the foundation for addressing all of the scientific and technical objectives under consideration, including which NEOS, if any, could be a threat to the Earth capable of "global devastation, " or those objects with diameters greater than 1 km. With a more complete inventory of objects, it will be possible to obtain more incisive information concerning their orbital distributions. This, in turn, will lead to a better understanding of families of objects and their interactions with one another. It may also lead to identification of entirely new families and groups. In addition, objects suitable for future space missions will be identified. After only 15 months, and the discovery of many unusual objects, these goals are being realized.

Telescope Site

The Air Force 1 m GEODSS telescope is located at 10,500 ft at the summit of the Haleakala extinct volcano where a complex of Air Force telescopes are used for satellite surveillance. In conjunction with the GEODSS/ NEAT program, and co-located at the site, the Air Force Maui Optical Site (AMOS) 1.2 m telescope is utilized for follow-up purposes, producing a very effective and valuable supplement to the discovery program.

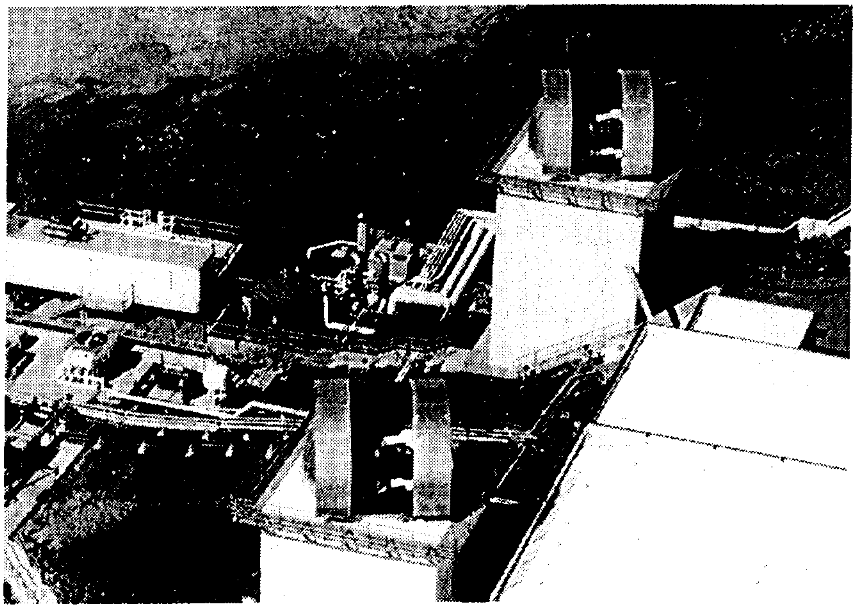

FIGURE 2. Aerial photograph of Air Force telescope facility in Mt. Haleakala, Maui, HI.

NEAT CAMERA

Version I

JPL designed and fabricated the NEAT camera and computer system. Version I of the camera employed a 2048 x 2048 Loral CCD chip with 15 micron pixels. This gave a scale of 1.43″/pixel and covered 0.64 square degrees per image when coupled to the 1 m f/2.15 GEODSS telescope. This smaller CCD was used from December, 1995 through March, 1996,

Version II

In April 1996, NEAT Version II was installed on GEODSS which is a 4096 x 4096 element Loral CCD chip, also with 15 micron pixels. The scale therefore remains the same, but the camera now covers more than 2.5 square degrees of sky in each frame and uses the full field of the GEODSS telescope. This CCD has four amplifiers on the chip and can be read out in 80 sec. With each image size at 33 Mbytes, an entire night can produce 4–5 Gbytes of data.

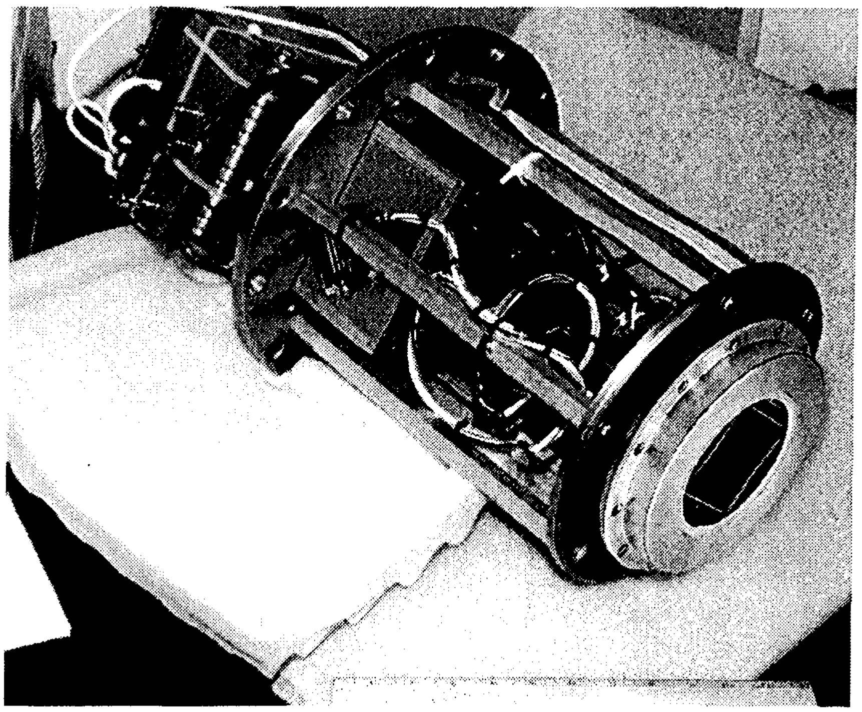

FIGURE **3. Photograph of NEAT camera in frame (housing) ready for telescope installation after the Ebsicon detector has been removed.**

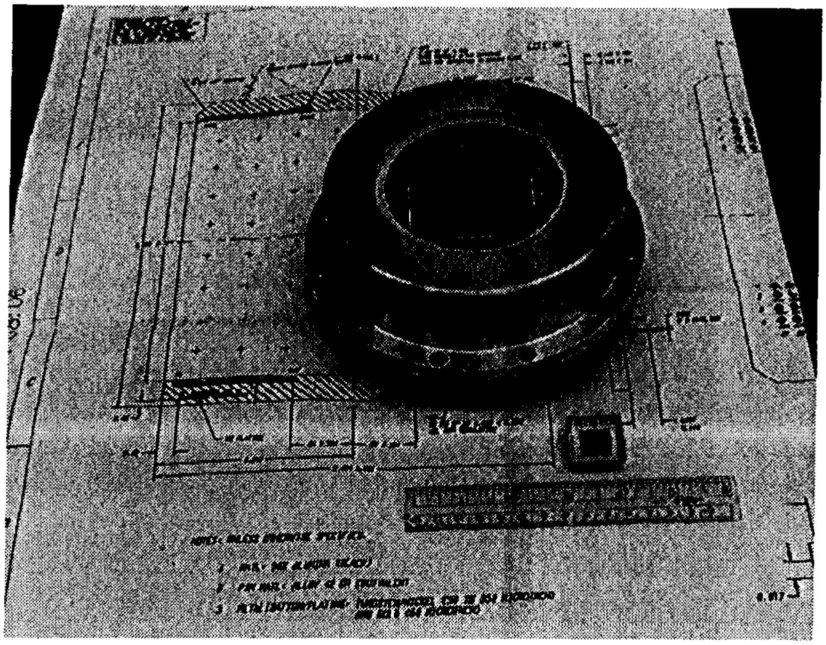

FIGURE 4. **Photograph 4k x 4k CCD chip.**

Version III

The NEAT Version 111 will be using new analog chain electronics from San Diego State University scheduled to be on-line in May, 1997. This will provide faster CCD chip read-out time which will result in an increase of sky coverage by 4 to 10 times. NEAT Version 111 will cover about 1000 square degrees per night.

AUTOMATIC DATA ANALYSIS SYSTEM

The automatic data analysis software examines the three images taken at the same sky positions. After the dark frames are subtracted, the software registers the images and removes any stationary objects, e.g., stars, galaxies, and/or permanent artifacts. Bright stars arc fitted to the Guide Star Catalog to determine the conversion between x–y pixels and RA and Dec. Small areas, 25 pixels squared, around the objects that have been determined to have moved linearly and consistently over the time period of the three exposures are saved. These "patches" are transmitted to JPL in the morning. The entire image, however, is also saved to tape for shipment to JPL after the observing run. During the morning, the patches are reviewed as to which objects are real. The positions of the real objects are then reported to the Minor Planet Center. Follow-up observations of any interesting object are made the next night. A representation of the three images follows,

The candidate object appears to move from the upper left to the lower right. Each small panel is a 25 x 25 pixel subimage extracted from the 4096 x 4096 pixel raw images. The moving object is found at 3 different positions during the 3 observation times. The top 3 panels are centered at position 1 during times 1–3, The moving object is centered in panel 1 only. The middle 3 panels are centered at positions 2 during times 1–3. The moving object is centered in panel 2 only. The bottom 3 panels are centered at position 3 during times 1–3. The moving object is centered in panel 3 only. Notice that fixed stars, if any, remain in the same relative position in all 3 horizontal panels. To review, the moving objects can only appear in the center of the panels in the upper-left to lower-right diagonal. All of the other panels are "anticoincidence" tests. The object can not be centered in any of them,

Another feature of the NEAT software analysis is each object's motion plot. The diagram to the right of the images depicts objects' motion in degrees per day, along the ecliptic longitude (horizontal axis) and latitude (vertical axis) directions. In Fig. 5, the object, 1996 T05, is moving at -0.42° per day, mostly in ecliptic latitude. The polygon shows the boundaries for the expected motions of main-belt asteroids. 1996 T05 is a near-Earth asteroid, an Earth-approaching Amor, consistent with the fact that its motion falls outside the polygon. In some cases the polygon delineating the main-belt motions will not be closed because the boundaries are not known precisely.

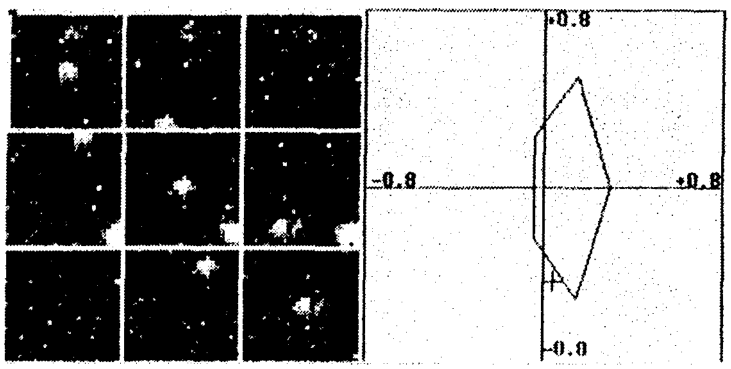

FIGURE 5. **Transmitted "patches" with motion plot of 1996 TO5.**

TABLE OF SIGNIFICANT DISCOVERIES: **NEAT Near-Earth Asteroid Discoveries**

Designation	a	e	*i*	*q*	Period	Arc	H-Mag	MPC Ref.
1996 EN	1.507	0.431	37.95	0.857	1.85	2 opp	16.50	28618
1996 EO	1.341	0.401	21.60	0.804	1.55	39	19.00	27328
1996 FQ3	2.031	0.471	1.07	1.075	2.89	122	21.00	27731
1996 FR3	2.165	0.795	8.31	0.443	3.19	87	17.00	27457
1996 KE	2.565	0.537	24.31	1.187	4.11	60	19.00	27569
1996 PH2	2.115	0.380	13.91	1.311	3.08	25	20.00	27884
1996 RY3	1.211	0.139	37.42	1.042	1.33	16	21.00	28053
1996 RC4	1.704	0.227	29.52	1.317	2.22	33	18.00	28619
1996 SK	2.428	0.797	1.96	0.494	3.78	82	17.00	28890
1996 T05	2.382	0.517	21.00	1.152	3.68	96	17.00	28864
1996 TD9	1.333	0.404	5.02	0.795	1.54	4	24.00	28055
1996 TE9	1.793	0.326	21.64	1.209	2.40	54	19.00	28597
1997 AC11	0.914	0.369	31.80	0.577	0.87	9	20.80	28813
1997 GH3	2.439	0.565	2.96	1.061	3.81	3	17.00	MPEC 97-G03

NOTABLE NEAT DISCOVERIES

NEAT has discovered bright (large) asteroids, as well as faint objects, and many of moderate faintness, demonstrating the excellent capability of the NEAT camera combined with the 1 m Air Force telescope.

Diffuse and elongated images also have been detected and identified as comets, new or independently found, as well as asteroids moving rapidly during the exposure. Both the hardware and software were brought on line in a relatively short period of time from concept to operation and at a modest cost.

"Potentially hazardous asteroids" (PHAs) are defined as asteroids which can come within 5 million km to the Earth or about 20 times the distance of the Moon [10]. These asteroids could be perturbed into a collision trajectory within about 100 years. None of the 88 currently known PHAs greater than 1 km in diameter, nine discovered in 1996 (3 by NEAT), will actually be a threat in less than 1000 years. Estimates indicate that there are 1000–2000 undiscovered PHAs. The odds of an impact from one of these is about 1 in 1000 within 100 years.

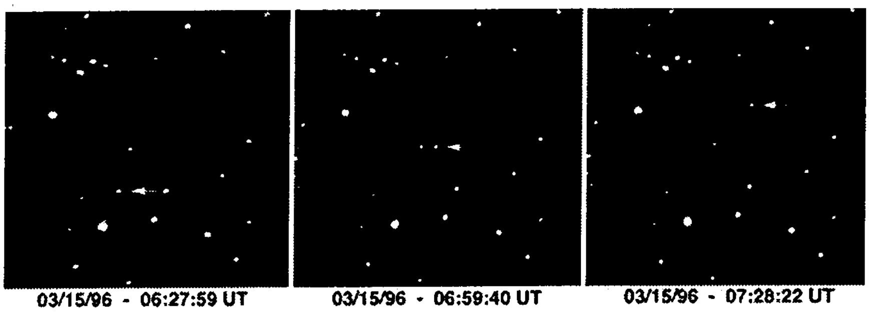

FIGURE 6. NEAT's **first Earth-crossing asteroid was 1996 EN, a "PHA," found in March 1996. It is a large body of 3 km in diameter and is a deep Earth-crosser. However, with a high inclination to the ecliptic, the chance of impacting the Earth is less likely.**

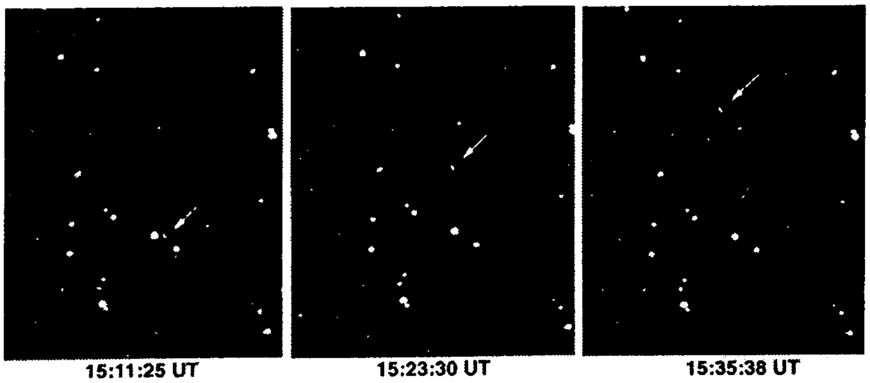

FIGURE 7. NEAT **discovered its first NEA of 1997 on 1/10/97. Aten class asteroid, 1997 AC11 is imaged here five days after its discovery. It is the first Aten discovered with NEAT and is one of only 24 Atens, i.e., asteroids with semimajor axes less than 1 astronomical unit, currently known.**

NEAT's first Earth-crossing asteroid was 1996 EN, a "PHA," found in March 1996. It is a large body of 3 km in diameter and is a deep Earth-crosser. However, it has a high inclination of 31° to the ecliptic which makes the chance of impacting the Earth less likely (see Fig. 6).

1997 AC11, the first Aten discovered by NEAT, has an high inclination and a small orbit. It is the 24th Aten asteroid discovered since 1976, when 2062 Aten was found by Helin at Palomar, the first asteroid with an orbit smaller than the Earth's and a period less than one year. On January 10, 1997 when it was discovered it was moving 1.8° per day and accelerated relative to the Earth during NEAT's observing period so that on January 15, it was traveling at 3.9° per day (see Fig. 7).

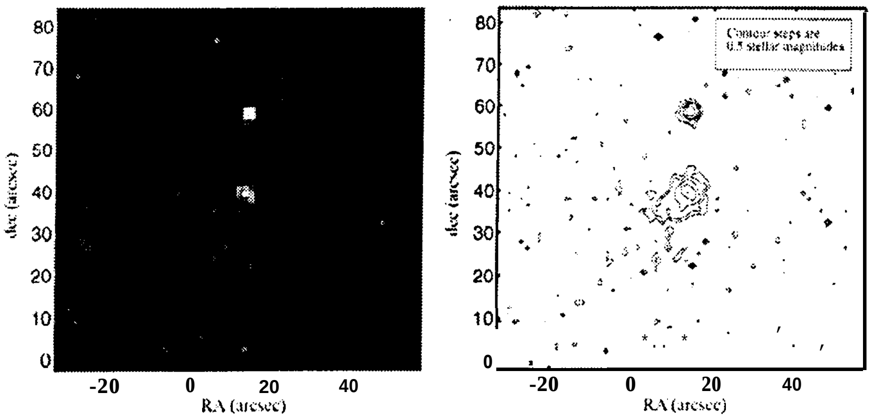

FIGURE 8. **Discovery image of Comet C/1996 El (NEAT) as observed with NEAT. Image contours on right are in 0.5 magnitude steps. Object to the north of the comet is a star. (Image analysis by S. Shaklan/S. Pravdo).**

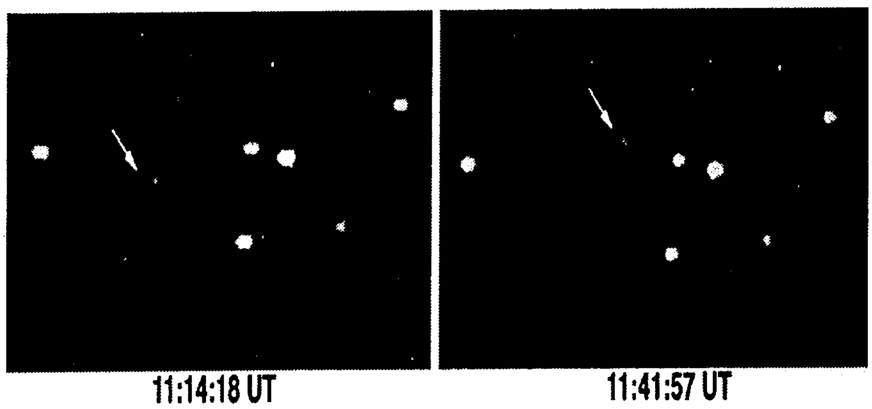

FIGURE 9. **Parabolic Comet 1997 Al (NEAT) as observed with NEAT on January 15, 1997.**

TWO LONG-PERIOD COMETS

Comet 1996 El (NEAT) was discovered March 15, the first major discovery of the new program (see Fig. 8). The comet, which has a parabolic orbit, is highly inclined to the ecliptic plane and made its closest approach to the Sun on 27 July 1996 at 1.36 AU. Upon discovery, it was diffuse with strong central condensation and a 15 arcsec tail.

Comet 1997 Al (NEAT) was the first comet discovered in the new year on January 7, 1997 (see Fig. 9). It has a parabolic orbit and had a long observing window allowing observations from around the world. When discovered, it was at 3.5 AU and moved closer towards perihelion at 3.1 AU on June 19, 1997,

UNIQUE OBJECT

1996 PW has remained asteroidal in appearance throughout its observing window, but it's orbit is similar to that of a long-period comet. It has an orbit of high inclination (29.8") and a period of ≈5900 years. Assuming a stony asteroid, its diameter would be about 8 km. If a typical cometary albedo is assumed, it could be about 15 km in diameter. Gareth Williams (Minor Planet Center) on reviewing the submitted NEAT data, noted the unusual motion of this unique, slow-moving object.

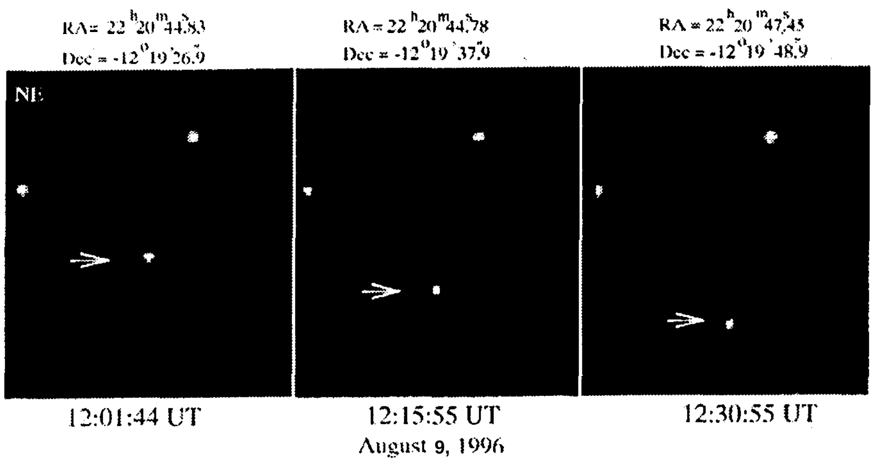

FIGURE 10. NEAT **discovery image of 1996 PW obtained on August 9, 1996. (See also M. P.E. C. 1996 -P03, -Q03, IAUC 6452). (Imagery by S. Shaklan/S. Pravdo.)**

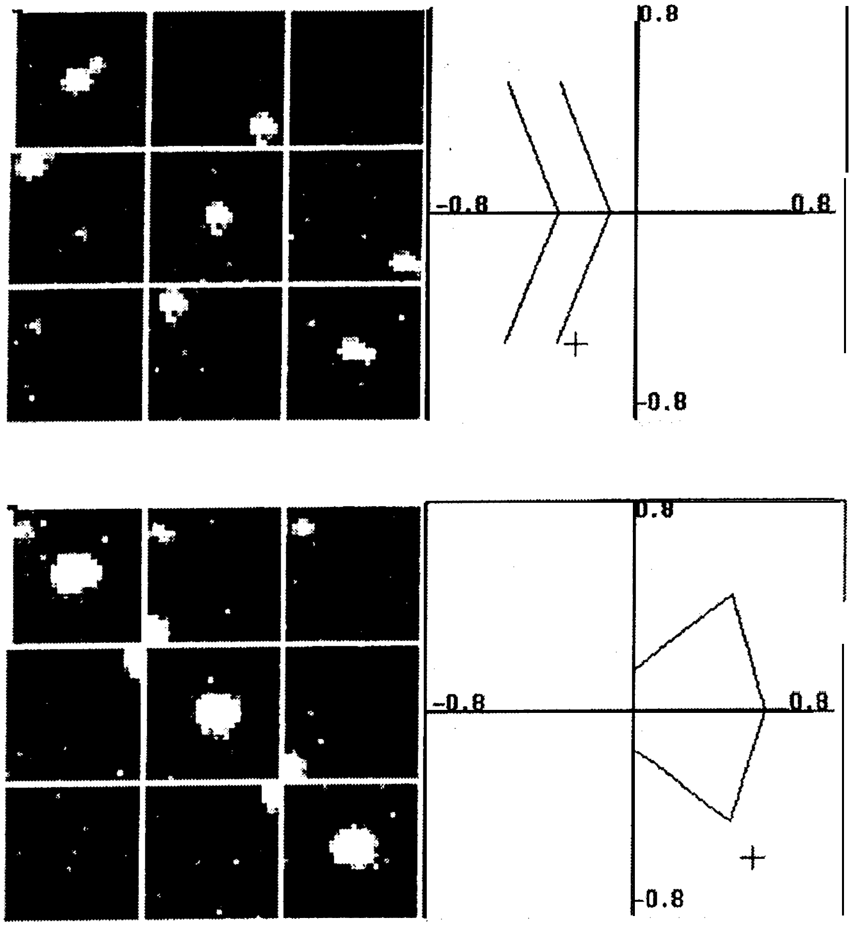

FIGURE 11. **Mars-crossing asteroids 1997 C05 (top) and 1997 CZ5 (bottom). Both discovered by NEAT during its February 1997 observing run.**

Figure 10 is the discovery image of 1996 PW, discovered with NEAT on August 9, 1996. It is a unique object with perihelion between Jupiter and Mars — about 2.5 AU — and an aphelion estimated at 652 astronomical units (see also M. P.E. C. 1996 -P03, -Q03, IAUC 6452, MPC 28618). With discoveries like 1996 PW, distinctions between asteroids and comets become more blurred and challenges us to understand the history and nature of this puzzling object.

OTHER UNUSUAL DISCOVERIES: MARS-CROSSERS

NEAT discovered two new high-eccentricity Mars-crossing asteroids whose orbital elements are given in Minor Planet Electronic Circulars. They are classified among 106 unusual objects. 1997 CZ5 (Fig. 11, bottom) is one of the larger ones — 5 to 12 km (3 to 8 miles) diameter — ranking 16th in size. It was discovered with NEAT on 2/7/97 moving 0.75° per day and recovered on subsequent days by NEAT and other observers worldwide. 1997 C05 (Fig. 11, top) was discovered with NEAT on 2/6/97 moving 0.6° per day and recovered on subsequent days by NEAT and other observers worldwide. It is considerably smaller — 1 to 2 km (about 1 mile) diameter. Both have perihelia between 1.3 and 1.4 astronomical units, just beyond the 1.30 AU limit required for classification as Amor Near-Earth asteroids. As such, they may be precursors to NEAs, transitioning after gravitational perturbations move their orbits closer to the Earth.

FUTURE OF NEAT

The future plans for the NEAT program are to continue to increase the discovery rate, to essentially 90 percent completeness of NEAs larger than 1 km in diameter in the next decade and provide partial inventory of other smaller objects of interest to the science community. In principle, additional NEAT cameras can be placed on other GEODSS telescopes located throughout the world to dramatically increase NEO discoveries. A NEAT/GEODSS network would collaborate with the international Spaceguard Survey.

COORDINATION AND THE SPACEGUARD CONCEPT

At present only two modern NEO discovery programs are fully in operation in the U. S., NEAT and Spacewatch (Gehrels, 1996). NEAT covers about 1000 square degrees/night to about magnitude 20.0 while Spacewatch observes about ten percent of the NEAT coverage, to about magnitude 22. Both systems are soon to enjoy upgrades, thereby increasing their sky coverage dramatically. Other systems from around the world are expected to become operational in coming months and years. NEAT and Spacewatch are the first participants of the international Spaceguard Survey.

An important aspect of the NEAT/GEODSS program, is the need for follow-up of the many new discoveries. The response from the international astronomical community has been outstanding (see the following discovery announcement and observations of Comet NEAT, C/1997 Al; IAUC 6532, 6534, MPECs 1997 A03) illustrating the wide representation of countries and astronomers contributing observations. Planetary defense from potentially dangerous NEOS is an international concern, requiring participation from all countries of the world [15], [16].

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CONET 1997 Al

E. F. Helin, Jet Prpulsion Laboratory, on behalf of the Near-Earth-Asteroid Tracking Team (Cf. IAU 6341), reports tha discovery of a comet on images obtained by the on-site USAF/Ground-based Elect ro-Optical Deep Space Surveillance Team in Hawaii. Available precise positions:

1997 UT	R.A. (2000)	DeCl.	ml	Observer
Jan. 10.51495	9 39 18.96	+16 26 18.9	18.6	Helin
10.52334	9 39 17.97	+16 26 28.9	18. 8	"
10.53174	9 39 17.04	+16 26 38.6	18.9	"
11.33935	9 37 46.18	+16 42 31.0	18.9	Rabinowitz
11.34959	9 37 45.11	+16 42 43.9		"

E. F. Helin, X. J. Lawrence and S. Pravdo (Haleakala-NEAT/GEODSS). 1-m f/2. 2 Ritchey-Chretien + CCD. Images clearly diffuse.
D. L. Rabinowitz (Table Mountain Observatory) . 0. 6-m reflector + "cCD. Naar limiting magnitude of exposure. 15 coma. extending asymmetrically to the south.

1997 January 11 (?532) Brian G. Marsden

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COMET c/1997 Al (NEAT)

Further precise CCD positions have been reported as follows:

1997 UT	R.A. (2000)	Decl	ml	Observer
Jan. 9.65241	9 40 54.00	+16 09 29.4	18.5	Kobayashi
9.67270	9 40 51.96	+16 09 52.0		"
11.3865a	9 37 40.78	+16 43 27.4	18.9	Helin
11.40340	9 37 38.85	+16 43 46.6	18.7	"
11.61977	9 37 13.96	+16 48 03.6	18.2	"
11.63868	9 37 11.67	+16 40 25.7	18.2	"
11.79751	9 36 53.65	+16 51 34.7	19.4	Z hu
11.80222	9 36 53.07	+16 51 40.8		"
12.44963	9 35 38.41	+17 04 33.5	16.6	Helin
12.47042	9 35 35.91	+17 04 58.7	18.7	"
12.58014	9 35 23.25	+17 07 08.9		Abe
12.58494	9 35 22.6a	+17 07 15.0		"
12.58.989	9 35 22.21	+17 07 19.8	18.5	Sugie
12.59722	9 35 21.20	+17 07 30.0		"

T. Kobayashi (Oizumi). o. 25-m f/4.4 reflector. Prediscovery images.
E. Helin, X. J. Lawrence, S. Pravdo and D. L. Rabinowitz (Haleakala-NEAT/GEODSS). 1-m f/2.2 Ritchey-Chretien.
J. Zhu and J. Ma (Xinglong). 0.60-m Schmidt. Measurer Zhu.
H. Abe (Yatsuka). 0.26-m f/6.0 reflector. Communicated by S. Nakano.
A. Sugie (Dynic). o. 60-m f/3.7 reflector. Communicated by Nakano.

Parabolic orbital elements f rem 16 observations Jan. 9-12:

T = 1997 Juna 17.208 TT   Peri. = 39.270
Node = 135.774   2000.0
q = 3.17375 AU   Incl . = 145.069

1997 TT	R. A. (2000)	DeCl.	Delta	r	Elong.	Phase	ml
Jan. 12	9 36.51	+16 55.6	2.616	3.508	150.9	7.8	18.5
17	9 26.41	+18 37.0	2.554	3.489	158.6	5.9	18.5
22	9 15.40	+20 21.3	2.505	3.469	166.3	3.8	18.4
27	9 03.57	+22 06.3	2.471	3.450	173.0	2.0	18.3
Feb. 1	8 51.11	+23 49.5	2.452	3.432	173.1	2.0	18.3
6	8 38.22	+25 2a.6	2.448	3.414	166.3	3.9	18.3
11	8 25.16	+27 01.3	2.460	3.397	158.5	6.1	18.3

1997 January 12 (6534) Brian G. Marsden

Tbe Minor Planet Electronic Circulars contain information on unusual minor planets and routine data on comets. They are published on behalf of Commission 20 of the International Astronomical Union bv the Minor Planet Center, Smithsonian Astrophysical Observatory, Cambridge, 34A 02138, U.S.A.

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URL http: //cfa-www.harvard.edu/cfa/ps/mpc.html

COMET C/1997 M (NEAT)

Observation:

CJ97AO1O C1997 01 09.65247 09 40 54.40 +16 09 29.4	18,5 T	411
cJ97AO1O C1997 01 09.67270 09 40 51.96 +16 09 52.0		411
CJ97AO1O C1997 01 10.51495 09 39 18.96 +16 2618.9	18.6 T	566
CJ97AO1O C1997 01 10052334 09 39 17.97 +16 2628.9	18.8 T	566
CJ97AO1O C1997 01 10.53174 09 39 17.04 +16 26 38.6	18.9 T	566
CJ97AO1O C1997 01 11.33935 09 37 46.18 +1642 31.0	18.9 T	673
CJ97A010 C1997 01 11.34959 09 37 45.11 +16 4243.9		673
CJ97AO1O C1997 01 11.38658 09 3740.78 +16 43 27.4	18.9 T	566
cJ97AO1O C1997 01 11.39499 09 37 39.83 41643 37.3	18.7 T	566
cJ97AO1O C1997 01 11.40340 09 37 38.85 +16 43 46.6	18.7 T	566
cJ97AO1O C1997 01 11.61977 09 37 13.96 +1648 03.6	18.2 T	566
CJ97AO1O C1997 01 11.63025 0937 12.75 +16 4816.3	18.5 T	566
CJ97A010 C1997 01 11.63868 09 37 11.67 +16 48 25.7	18.2 T	566
CJ97AO1O C1997 01 11.79278 09 36 54.17 +16 51 30.2		327
CJ97AO1O C1997 01 11.79751 09 36 53.65 +16 51 34.7	19.4 T	327
CJ97A010 C1997 01 11.80222 0936 53.07 +16 51 40.8		327
CJ97AO1O C1997 01 11.80696 09 36 52.48 +1651 46.3		327
CJ97AO1O C1997 01 12.44963 093538.41 +17 0433.5	18.6 T	566
CJ97A010 C1997 01 12.45994 09 3537.05 +17 0447,0	19.2 T	566
CJ97A010 C1997 01 12.47042 09 35 35.91 +17 04 58.7	18.7 T	566
CJ97AO1O C1997 01 12.57534 09 35 23.79 +17 07 02.1	18.4 T	367
cJ97AO1O C1997 01 12.58014 09 3523.25 +17 07 08.9		367
CJ97AO1O C1997 01 1205849409 3522.68 +17 0715.0		367
CJ97A010 C1997 01 12.58889 093522.21 +17 0719.8	18.5 T	402
CJ97AO1O C1997 01 12.59306 09 3521.70 +17 0724.5		402
CJ97AO1O C1997 01 12.59722 09 3521.20 +1707 30.0		402
CJ97AO1O C1997 01 12.91464 09 34 44.08 +17 13 49.2	18.5 T	046
CJ97A010 C1997 01 12.91691 09 34 43.72 +1713 52.7		046
CJ97A01O C1997 01 12.91902 09 34 43.40 +17 13 55.9		046
CJ97AO1O C1997 01 12.9209609 34 43.33 +171357.7		046
CJ97AO1O C1997 01 12.92786 09 34 42.36 +17 14 07.2		046
CJ97AO1O C1997 01 13.46442 09 33 39.01 +17 24 54.4	18.2 T	566
CJ97A010 C1997 01 13.47283 09 33 38.00 +17 25 04.2	18.1 T	566
CJ97AO1O C1997 01 13.48124 09 33 36.98 +17 2514.1	18.3 T	566
CJ97AO1O C1997 01 13.55558 09 33 28.35 +17 26 42.6		867
CJ97AO1O C1997 01 13.56218 09 33 27.50 +17 26 51.0		867
CJ97A010 C1997 01 13.5677309 33 26.79 +17 26 58.2		867
CJ97A010 C1997 01 13.64462 09 33 17.62 +17 28 32.0		900
CJ9"IAO1O C1997 01 13.66438 09 33 15.17 +17 28 55.9		900
CJ97A010 C1997 01 13.67892 09 33 13.38 +17 29 14.3		897
CJ97AO1O C1997 01 13.69010 09 33 12.14 +17 2927.3	17.2 T	360
cJ97AO1O C1997 01 13.69300 09 33 11.81 +17 29 29.9		1197
CJ97AO1O C1997 01 13.69368 09 33 11.64 +17 2934.3	18.4 T	422
CJ97AO1O C1997 01 13.69705 09 33 11.30 +17 29 35.9		360

—*continued*

Observations — continued

CJ97AO1O C1997 01 13.70028 09 33 10.88 +17 29 42.9	18.5 T	422
CJ97AO1O C1997 01 13.70093 09 3310.81 +17 2940.9	17.7 T	897
CJ97AO1O C1997 01 13.70330 09 33 10.52 +17 29 43.0		360
CJ97AO1O C1997 01 13.70562 09 33 10.22 +17 29 48.1	18.5 T	422
CJ97AO1O C1997 01 14.08245 09 3225.10 +17 ?7 22.2	17.8 T	046
CJ97AO1O C1997 01 14.08608 09 3224.67 +17 37 26.6		046
CJ97A010 C1997 01 14.08823 09 32 24.38 +17 37 29.2		046
CJ97AO1O C1997 01 14.1063S 09 3222.17 +17 37 51.1		557
CJ97AO1O C1997 01 14.10951 09 32 21.80 +17 37 S5.0	17.9 N	557
CJ97A(J1O C1997 01 14.11243 09 3221.43 +17 37 58.5	16.9 T	557
CJ97AO1O C1997 01 14.54427093129.24 +17 4644.8	18.2 T	566
CJ97AO1O C1997 01 14.55267 09 3128.25 +17 4655.0	18.2 T	566
CJ97AO1O C1997 01 14.56109 09 3127.19 +17 4706,0	18.1 T	566
CJ97AO1O rC1997 01 15.05873 09 3026.61 +17 57 11.8	17.81'	118
CJ97AO1O rC1997 01 15.06181 09 30 26.21 +17 57 15.4		118
CJ97AO1O rC1997 01 15.06903 09 3025.34 +17 57 24.8		118
CJ97AO1O C1997 01 15.08287 09 3023.64 +17 57 40.5	17.0 T	966
CJ97A010 C1997 01 15.08780 09 30 23.00 +17 57 46.8		966
CJ97A010 C1997 01 15.09020 09 3022.82 +17 57 50.6		966
CJ97AO1O C1997 01 15.09236 09 30 22.53 +17 57 53.8		966
CJ97A010 C1997 01 15.16380093013.64 +17 5920.4	17.9 T	046
CJ97A010 C1997 01 15.16507 09 30 13.50 +17 5922.0		046
CJ97AO1O C1997 01 1S.16728 09 30 13.23 +17 59 25.1		046
CJ97AI31O C1997 01 15,17091 09 30 12.74 +17 59 29.3		046
CJ97AU1O C1997 01 15.41022 09 29 43.42 +18 04 22.5		658
CJ97AO1O C1997 01 15.41623 09 29 42.65 +18 04 29.3		658
CJ97AO1O C1997 01 15.42234 092941.88 +18 0436.8		658

Observer details:

046 **Klet. Observers** J. **Ticha, M. Tichy, Z. Moravec. 0.57-m** f/5.2 reflector + CCD.
118 **Modra. Observers P. Koleny,** L. **Kornos.** 0.6-M **f/5.5 reflector** + **CCD.**
327 Peking Observatory, **Xinglong** Station. **Observers** J. **Zhu,** L. **J. Ma.** 0.6-m Schmidt + **CCD.**
360 **Kuma Kogen.** Observer A. **Nakamura. 0.60-M** f/6. **0 Ritchey-Chretien + CCD.**
367 **Yatsuka. Observer H.** Abe. *0.26-m* **f/6. 0** reflector + **CCD.**
402 **Dynic Astronomical Observatory. Observer** A. **Sugie.** ,0.60 -m f/3.7 reflector + **CCD.**
411 **Oizumi.** Observer T. **Kobayashi. 0.41-In f/4.3** reflector + CCD. **Prediscovery** images.
422 **Loomberah.** *observer C.* J. **Garradd. 0.25-m f/4.1 reflector + CCD.**
557 **Ondrejov. Observers P. Pravec,** L. **Sarounova.** *0.65-m* **f/3.6 reflector + CCD.**
566 **Haleakala-NEAT/GEODSS. Observers** R. F. **Helin,** S. **Pravdo,** K. **J.** Laurence, D. **L. Rabinowitz** for the WEAT **team.** I. O-m **f/2.2 GEODSS telescope + CCD."**
658 **Dominion Astrophysical** observatory. Observer **G.** C. L. **Aikman. 1.82-m** reflector + CCD.
673 Table Mountain **Observatory, Wrightwood. Observer** D. L. **Rabinowitz.** 0.6-m reflector + CCD.

Observations — continued

867 Saji Observatory. Observers M. Yamanishi, A. Miyamoto, M. Aimoto, T. Oribe. 1.03-m f/4.8 reflector + CCD.
897 Chiyoda. Observer T. Kojima. 0.25-m f/6. O reflector + CCD.
300 Moriyama. Observer Y. Ikari. 0.25-m f/6.3 reflector + CCD.
966 Church Stretton. Observer S. P. Laurie. 0.25-M Schmidt-Cassegrain + CCD.

Orbital elements:
C/1997 A1 (NEAT)

T 1997 June 19.4S397 TT					Marsden
q	3.159? 095		(2000.0)	P	Q
		Peri.	39.34749	-0.18209130	+0.89846855
		Node	135.76550	+0.69042376	-0.17245471
e	1.0	Incl.	145.06305	+0.70011270	+0.40374948

From 65 observations 1997 Jan. 9-15.

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