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This amended report supersedes the report dated Dec. 14 and differs only in the listed numbers in the abstract of objects discovered by Spacewatch during the report period.

14. ABSTRACT

Spacewatch is an exploration of the whole solar system for minor planets and comets, from the inner solar system to beyond Neptune's orbit. During this report period, Spacewatch discovered 23 Earth-approachers (EAs), 9,910 main belt asteroids (MBAs), a new satellite of Jupiter, 2 comets, 9 Centaurs or scattered-disk objects, and 6 Trans-Neptunian Objects (TNOs). Spacewatch made a new estimate of the number of km-sized EAs, from which it has been estimated that only 50% of such objects have been found by all groups and that the remainder of km-sized EAs may tend to have orbits that make them more difficult to detect. Relevant to that, Spacewatch continued to develop new software and equipment that will provide sensitivity to slower angular motion, dimmer targets, and faster coverage of sky area. Spacewatch extended knowledge of the distribution of MBAs vs. absolute magnitude by 4 mags, found departures in this distribution from a simple power-law, and contributed this fit to the first empirical determination of the transition from mechanical strength to gravitational bonding in the critical specific energy vs. size relation of asteroids. In the outer solar system, Spacewatch extended knowledge of the luminosity distribution of Centaurs and Trans-Neptunians to brighter magnitudes.

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ABSTRACT

Spacewatch is an exploration of the whole solar system for minor planets and comets, from the inner solar system to beyond Neptune's orbit. During this report period, Spacewatch discovered 81 Earth-approachers (EAs), 21,395 main belt asteroids (MBAs), a new satellite of Jupiter, 5 comets, 9 Centaurs or scattered-disk objects, and 6 Trans-Neptunian Objects (TNOs). Spacewatch made a new estimate of the number of km-sized EAs, from which it has been estimated that only 50% of such objects have been found by all groups and that the remainder of km-sized EAs may tend to have orbits that make them more difficult to detect. Relevant to that, Spacewatch continued to develop new software and equipment that will provide sensitivity to slower angular motion, dimmer targets, and faster coverage of sky area. Spacewatch extended knowledge of the distribution of MBAs vs. absolute magnitude by 4 mags, found departures in this distribution from a simple power-law, and contributed this fit to the first empirical determination of the transition from mechanical strength to gravitational bonding in the critical specific energy vs. size relation of asteroids. In the outer solar system, Spacewatch extended knowledge of the luminosity distribution of Centaurs and Trans-Neptunians to brighter magnitudes.

Participating Professionals (all at the Lunar and Planetary Laboratory):

Terrence H. Bressi (B. S., Astron. & Physics)	Engineer
Anne S. Descour (M. S., Computer Science)	Senior Systems Programmer
Tom Gehrels (Ph. D., Astronomy)	Professor, Senior Co-I, and observer
Robert Jedicke (Ph. D., Physics)	Principal Research Specialist
Jeffrey A. Larsen (Ph. D., Astronomy)	Principal Research Specialist and observer
Robert S. McMillan (Ph. D., Astronomy)	Associate Research Scientist, PI, & observer
Joseph L. Montani (M. S., Astronomy)	Senior Research Specialist and observer
Marcus L. Perry (B. A., Astronomy)	(Chief) Staff Engineer
James V. Scotti (B. S., Astronomy)	Senior Research Specialist and observer

PURPOSE AND JUSTIFICATION

The purpose of the Spacewatch project is to explore the various populations of small objects throughout the solar system. Statistics on all classes of small bodies are needed to infer their physical and dynamical evolution. More Earth Approachers need to be found for spacecraft missions and to assess the impact hazard. (We have adopted the term "Earth Approacher", EA, to include all those asteroids, nuclei of extinct short period comets, and short period comets that can approach close to Earth. The adjective "near" carries potential confusion, as we have found in communicating with the media, that the objects are always near Earth, following it like a cloud.) Persistent and voluminous accumulation of astrometry of incidentally observed main belt asteroids (MBAs) will eventually permit the Minor Planet Center (MPC) to determine the orbits of large numbers (tens of thousands) of asteroids. Such a large body of information will ultimately allow better resolution of orbit classes and the determinations of luminosity functions of the various classes. Comet and asteroid recoveries are essential services to planetary astronomy. Statistics of objects in the outer solar system (Centaurs, scattered-disk objects, and Trans-Neptunian Objects; TNOs) ultimately will tell part of the story of solar system evolution. Spacewatch led the development of sky surveying by electronic means and has acted as a responsible interface to the media and general public on this discipline and on the issue of the hazard from impacts by asteroids and comets.

BACKGROUND AND CURRENT STATUS

CCD scanning was developed by Spacewatch in the early 1980s, with improvements still being made. Spacewatch was the first astronomical group to use drift scanning with a CCD, first to use CCDs to survey the sky for comets and asteroids, first to do astrometry on an asteroid with a CCD (1984 JZ on 1984 Apr. 28; numbered (3325) after our observation), first to do targeted astrometry of an EA with a CCD (1983 TB, now known as (3200) Phaethon, on 1984 Sep. 22), first to discover an asteroid with a CCD (the Trojan (3801) Thrasymedes), first to discover an EA with a CCD (1989 UP), first to discover an EA with software (1990 SS; now (11885)), first to discover a comet with a CCD (1991x; modern designation 125P/1991 R2), and first to discover an asteroid known to be monolithic (1998 KY_{26}). At the time of this writing, Spacewatch still holds the records for discovering the smallest known asteroid (1993 KA_2; H=29), the closest known approach of any asteroid to the Earth (1994 XM_1; 105,000 km), the object with the most Earthlike orbit (1991 VG), and the asteroid most accessible to spacecraft (the rapid rotator 1998 KY_{26}). As of 2000 Dec. 13, Spacewatch had discovered 228 EAs, 16 Centaurs or scattered-disk objects, 14 comets, 7 TNOs, and rediscovered one lost comet (P/Spitaler in 1993). Spacewatch has also made a total of 4,204 astrometric observations of comets, recovered 61 comets, and has reported 306,934 astrometric detections of asteroids, mostly in the main belt, including more than 40,956 for which provisional designations have been credited by the MPC to Spacewatch. A total of 4,849 positions of EAs have been reported by Spacewatch since 1984.

TECHNIQUE

Moving objects are discovered by scanning the sky with a charge-coupled device (CCD) electronic imaging detector on the 0.9-meter Spacewatch Telescope of the Steward Observatory, University of Arizona, located on Kitt Peak mountain in the Tohono O'odham Nation. The principles of Spacewatch observing have been described by McMillan and Stoll (1982), Frecker *et al.* (1984), Gehrels *et al.* (1986), McMillan *et al.* (1986), Gehrels (1991), Rabinowitz (1991), Perry and Frecker (1991), Scotti (1994), and Jedicke (1996). Each Spacewatch scan consists of three passes over an area of sky using a CCD filtered to a bandpass of 0.5-1.0 μm (approximately V+R+I with an effective wavelength on typical asteroids of 0.7 μm). The effective exposure time for each pass is 143 seconds multiplied by the secant of the declination. The area covered by each scan is 32 arcminutes in declination by about 28 time minutes in right ascension. The image scale is 1.05 arcseconds per pixel. Three passes take about 1.5 hours to complete and show motions of individual objects over a one hour time baseline. The limiting magnitude on slowly moving objects in good conditions is about 21.8. More than 2000 deg^2 are now being surveyed per year with the 0.9-m telescope.

PROGRESS AND ACCOMPLISHMENTS

Operations: We operated the 0.9-m Spacewatch Telescope smoothly and intensively before, during, and after the grant period, averaging 20 scheduled nights per lunation (month). Less than 1% of the observing time is lost due to equipment failures. During the period 1997 Nov. 1 - 2000 Oct. 31, Spacewatch reported 174,762 astrometric detections of asteroids (mostly MBAs) to the Minor Planet Center, including discoveries of 81 EAs, 5 comets, 9 Centaurs or Scattered-Disk Objects, and 6 Trans-Neptunian Objects (TNOs). From 1997 Nov. 1 through 2000 Oct. 31, Spacewatch also sent in 1,475 positional measurements of EAs. Larsen and Descour's IMPACT program (see below) doubled our rate of detection of MBAs and with time should prove to have increased our rate of detection of EAs. Four students were trained by Larsen and became regular observers. Observers Gehrels, Larsen, Montani, and Scotti continued their regular turns at the telescope, and in October 1999 McMillan began taking a monthly shift at the telescope as well. Spacewatch rediscovered minor planet (719) Albert which had been lost since its discovery in 1911, and discovered S/1999 J1, the 17th satellite of Jupiter. Not long after the expiration of this grant, Spacewatch also discovered 2000 WR106, the brightest TNO other than Pluto.

The Number of Large Earth-Approaching Asteroids: Using his debiasing technique on Spacewatch observations in collaboration with W. Bottke of Cornell Univ. and others, Jedicke has made a new estimate of the total number of EAs with $H \leq 18$. Their new estimate of the number of these EAs is 900 ± 100 (Bottke *et al.* 2000a). This is significantly less than the previously quoted value of 2000, and is in agreement with the estimate of 700 ± 230 extrapolated by Rabinowitz *et al.* (2000) from JPL/NEAT observations. The modeling used by Bottke *et al.* (2000a) involves the relative contributions of EAs from several dynamical processes that draw asteroids from the main belt into Earth-approaching orbits. Bottke *et al.* (2000a) also predict that most of the undiscovered EAs probably have more extreme values of *a, e,* and *i.* Thus to find the remaining objects, surveys will have to go fainter and be sensitive to slower angular motion, parameters that already distinguish Spacewatch from the other EA surveys.

Potentially Hazardous EAs:

Scotti discovered the closely-approaching EA 1997 XF_{11} that became the subject of media attention in March 1998 when the Minor Planet Center announced that in future decades it would approach so close to the Earth that the possibility of an impact could not be ruled out. Subsequent calculations and observations eliminated that alarm.

Because Spacewatch goes much fainter than other EA survey groups and Spacewatch observers can detect long, faint trails by visual inspection of the video display screen that software for starlike images can miss, detection of very nearby EAs is a characteristic of Spacewatch. Among the 12 known asteroids with minimum orbital intersection distances (MOIDs) less than 0.001 AU, 5 were found by Spacewatch (Bowell and Koehn 2000). Seven approaches ≤0.02 AU from the Earth will be made by EAs discovered by Spacewatch within the next hundred years (MPC web site 2000 Apr. 21).

Distribution of Sizes of MBAs and their Strengths:

The luminosity function of MBAs is relevant to physical studies of EAs because it is a cumulative record of collisional processing. Collisional processing depends on, among other things, the cohesiveness of asteroid material. Knowledge of the cohesion of EAs would guide methods to deflect their orbits and the design of mining techniques. Jedicke and Metcalfe (1998), analyzing Spacewatch observations of MBAs, found departures from a simple power law in their distribution of absolute magnitudes. The slope of this distribution and the kink at absolute magnitude $H \approx 13$ were then used by Durda, Greenberg, and Jedicke (1998) to derive information about the critical specific energy and the collisional processing of MBAs. This may have been the first empirical determination of the size-strength scaling relation for asteroidal material. It indicates that the transition between gravity-dominated and strength-dominated collision dynamics seems to lie in the vicinity of 150 m diameter where the critical specific energy, a measure of binding strength, is at a minimum. In other words, Durda, Greenberg, and Jedicke's (1998) results suggest that asteroids of 150 m diameter are the most weakly bound, with smaller objects being more monolithic and larger ones composed of pieces well under 150m in size, held together by mutual gravitation.

O'Brien and Greenberg (1999) point out that Durda *et al.'s* (1998) model for collisional evolution needs revision to bring it into agreement with cosmic-ray exposure ages of meteorites and the histories of cratering on asteroids (Chapman *et al.* 1996; Greenberg *et al.* 1994, 1996). However, Durda (1999 pers. comm.) says that the diameter at which the transition from mechanical strength to gravitational bonding occurs will not be affected by such revisions to his model. Indeed, it appears that the nongravitational Yarkovsky effect could drive migration slowly enough to explain the measured cosmic ray exposure ages of meteorites (Bottke *et al.* 2000b).

Rotation Rates as a Clue to Asteroid Cohesion:

Lightcurves of SEAs can also contribute to knowledge of asteroid cohesion. The maximum rotation rate as a function of asteroid size has long been known as a clue to the average size of the monolithic chunks making up asteroids (Harris 1996). Asteroids with absolute magnitudes $H < 22$ (diameter > 200 m) do not rotate faster than once in about 2 hours, suggesting that there are no monolithic asteroids larger than 200 m. That is apparently as fast as the larger asteroids can spin without the component pieces being separated by centrifugal "force" (Harris 1996). This is consistent with Durda, Greenberg, and Jedicke's (1998) finding based on modeling evolution of the size distribution by collisions, but is not a strong confirmation of it because at the time of Harris's work there were no rotation periods available for smaller asteroids. The maximum rotation rate as a function of diameter of smaller asteroids should eventually reveal the diameter below which monoliths are common.

Spacewatch has begun to make a contribution in this area. Gehrels discovered the SEA 1998 KY_{26} and Scotti observed its light-curve. Combined with data from two other observatories, these observations showed that the asteroid rotates with a period of only 10.7 minutes (an order of magnitude faster than any other asteroid known at that time) and an amplitude of 0.3 magnitudes. Combined with radar observations by Steve Ostro of JPL, this indicates that the object has to be a monolithic and slightly elongated spheroid only 30 m in diameter, not a rubble pile as inferred for larger asteroids (Davis *et al.* 1996; Harris 1996; Love and Ahrens 1996; Melosh and Ryan 1997). Multicolor photometry by Ostro's co-authors and Ostro's radar data show that the object appears to be a carbonaceous chondrite, probably derived from an impact crater event on a larger asteroid (Ostro *et al.* 1999). Since the discovery of 1998 KY_{26}, the LINEAR and Catalina groups have discovered three more SEAs that have rapid rotation rates (Pravec *et al.* 2000).

Review of Research on the Dynamics of Small Bodies in the Outer Solar System:

The study of the outer Solar System has become an important topic of research in recent years for several reasons. It was suggested by K.E. Edgeworth (1949) and G.P. Kuiper (1951) that there was no real reason to expect the region beyond the observable Solar System to be completely devoid of material. More recently Fernandez (1980) suggested that a low inclination belt of material, later dubbed the Kuiper Belt, might exist beyond Neptune that could be a significant source of the Jupiter Family of short-period comets. Early searches, including those of Tombaugh (1961) and Kowal (1989), were unsuccessful at finding the belt of material, but did discover Pluto and (2060) Chiron, two important members of the outer Solar System. Finally, Jewitt and Luu found the first of the Kuiper Belt objects beyond the orbit of Neptune in 1992 (Jewitt and Luu 1995).

Recent dynamical studies by Levison and Duncan (1997), Malhotra (1995, 1996), Morbidelli *et al.* (1995), and Morbidelli (1997) have helped to define the expected distribution and dynamical structure of material in the 30 to 50 AU trans-Neptunian region while opening up a number of questions concerning, for example, the relative number of objects at the 2:3 and 1:2 mean-motion resonances with Neptune. While about 24% of the TNOs appear to be in or near the 2:3 mean-motion resonance, there have been only about 3% found to date at the 1:2 mean-motion resonance. Malhotra (1996) expected to find about equal numbers of objects at both resonances. One explanation for the discrepancy of these studies with observations is that Neptune is likely to have migrated out to its present location, causing some mean motion resonance to be depleted with respect to other resonances. Discovery of more objects beyond Neptune should provide additional constraints on these dynamical models. Weidenschilling (1997) and Kenyon and Luu (1998) have estimated the accretion rates and other initial conditions of the TNO region, while Stern (1995) and Davis and Farinella (1997) have provided models of collisional evolution of objects beyond Neptune which can be tested by direct measurement of the size distribution.

Knowledge of the size distributions of the TNOs may shed light on the characteristics of the primordial nebula and accretion of Neptune and of the TNOs. It has also been suggested by Stern (1996) that the region beyond about 50 AU may be unaffected by mean-motion resonances with Neptune and accretion may have continued up to the present time, resulting perhaps in the development of Pluto sized bodies in the 50-100 AU distance range which will be within the range of Spacewatch. On the other hand, the deep survey by Allen *et al.* (2000) suggests an edge to the Kuiper Belt at about 50 AU. Discovery or non-discovery of such bodies would yield important clues to the surface density of the primordial Solar nebula and on the initial conditions in the observed outer Solar System.

Centaurs and Scattered-Disk Objects:

In their original definition, Centaurs were defined as asteroids or comet nuclei between the orbits of Jupiter and Neptune, each one crossing the orbit of at least one giant planet (Jedicke and Herron, 1997). The Centaurs were seen as dynamically derived from the Transneptunian population and it was hoped that observational limits to the Centaur population would provide complementary limits to the number of Centaurs in a steady-state model. Jedicke and Herron (1997) debiased early scans made with the 0.9 meter Spacewatch Telescope to establish and upper limit (2000) on the number of Centaurs in the absolute magnitude range $-4 < H < 10.5$. The implication is that although a transient population, the Centaurs may be as numerous as the MBAs over the same range of absolute magnitudes.

However, developments during this grant period have lead to the blurring of the distinction between Centaurs and "Scattered Disk" TNOs principally through Spacewatch discoveries of 1995 SN55 and 1999 TD10, which can be argued to meet criteria set for both TNOs and Centaurs. According to Marsden (2000), there are no dynamical reasons to make a distinction between scattered-disk objects and Centaurs. Thus the Centaurs seem to sit on a boundary between asteroids and comets. Therefore, studies of them are a vehicle for understanding the dynamical evolution of the outer solar system. Spacewatch has been a productive discoverer of Centaurs and will be improving this capability over the next couple of years.

Spacewatch Research on the Outer Solar System: The Spacewatch 0.9 meter is the smallest telescope in the world being used to find TNOs (not counting the original Lowell Observatory telescope which found Pluto). Because of our relatively large field of view and our bright limiting magnitudes compared to other surveys of the outer solar system, our primary contribution is in the discovery of the rarer, larger objects. Larsen and his students have reanalyzed 1483.8 square degrees of archived scans to a magnitude limit of V=21.8 using their new software which is sensitive to smaller angular displacements of images of objects. They discovered 5 new Centaurs/Scattered Disk Objects (out of a total of 7 detected) and 5 TNOs (out of a total of 9 detected) in this manner (Larsen *et al.* 2001a). After debiasing for observational selection effects, they have determined the bright ends of the cumulative luminosity functions (CLFs) of Centaurs and TNOs, adding a 0.7 mag brightward for TNOs and 3.5 mag brightward for Centaurs on the cumulative density surface plots, into regions previously described only in terms of limits. The CLF of the Centaurs seems to have the same power law as that of the TNOs. These findings are extrapolated to the estimates that there should be 100 Centaurs, 400 TNOs, and 70 Scattered Disk Objects brighter than R = 21.5.

Comets: In addition to Spacewatch's discovery of 5 comets in the normal course of survey scanning during this grant period, Spacewatch recovered 4 comets since 1997 Nov. 1 and reported 499 positional measurements of 109 comets.

Image Analysis Software: Spacewatch's Moving Object Detection Program (MODP; Rabinowitz 1991) was constrained to process scans in real-time on a 1988-vintage computer. The necessarily simplified image detection and processing algorithms came with an efficiency cost. Jedicke and Herron (1997) placed MODP's efficiency at detecting asteroids at approximately 60%, which led to a substantial bias correction for their science analyses. Using more rigorous algorithms on a modern computer, Larsen developed a MODP replacement dubbed IMPACT: Image Motion Package for Asteroids, Comets, and Transneptunians (Larsen *et al.* 2001b). IMPACT has an advantage over the peak-pixel detection algorithm in MODP in that it requires that several pixels above threshold be spatially correlated in order to qualify as a detected image. As a result, IMPACT can find fainter objects. Since 1999 Sept. 29 it has been in use at the telescope. It finds 40% more asteroids per scan, brings the efficiency for V<20 to above 90%, affords 0.2 mag more sensitivity, and can detect smaller angular displacements than MODP. An example of the latter capability is our recent discovery of the first comet of the year 2000 (C/2000 A1).

New Telescope: This will be the largest telescope in the world dedicated full time to the search for previously unknown members of the solar system. Its 1.8-m aperture, sensitive CCD, and dedication to surveying will extend all of Spacewatch's exploration of the solar system to exciting new limits (Perry *et al.* 1998). "First Light" with it was accomplished during this grant period, including its first digital imagery of Earth-approaching asteroids.

Mosaic of CCDs: To increase the area covered by the 0.9-m telescope we have received a grant from NASA to pave the focal plane with a mosaic of four CCDs. We have taken delivery on four of EEV, Inc.'s 2048x4608 three-side buttable grade 1 CCDs with 13.5 μm pixels. They will be operated to the same limiting magnitude we have been reaching, to allow us to discover all of the same classes of moving objects, but at a much higher rate. The control and readout electronics are well along in development in our lab. We have received the field corrector lenses and the cryostat is nearly finished. The blank for the new primary mirror, needed to provide the appropriate focal length and figure for the required wide, flat, distortionless field of view, is being cast. Bids for polishing the mirror have been received, and fabrication of the lens cell and mirror cell has begun.

EDUCATION, PUBLIC OUTREACH, AND MEDIA CONTACT

These contributions by Spacewatchers are made without any compensation over and above regular University salaries.

Gehrels' educational contributions for the interval 1997 Dec. 1 through 2000 Oct. 31 began in the spring of 1998 with a presentation to the Tohono O'odham Tribal Council, and at Baboquivari High School in Sells, Tohono O'odham Nation, Arizona. In July and August 1998 he attended the American Geophysical Union (AGU) meeting in Taiwan. The statistics paper by Gehrels (1999) was the result of that trip. In Ahmedabad, India, Gehrels spoke before the UN Graduate School in Space Science with students from Bolivia, India, Indonesia, Mongolia, North Korea, Sri Lanka, and Uzbekistan; the paper by Bhandari and Gehrels (1999) was the result.

Gehrels also made two trips to schools in the Tohono O'odham Nation in the Spring of 1999. His trip of 1999 Sept. 23 - Oct. 9 was for a lecture in Los Angeles to the Space Frontier Foundation, two lectures in Bangalore, two in Ahmedabad, one in Amsterdam for the International Aeronautics Federation, and a presentation to Prince Bernhard of the Netherlands.

Gehrels served on the Dean's P&T committee, the Graduate Degree Certification committee, and as a Marshall at Commencements. He teaches "Universe and Humanity, Origin and Future," and is developing a textbook for that. He was specially invited to teach a UN Course at the Physical Research Laboratory in Ahmedabad, for graduate students from India, North Korea, Indonesia, Sri Lanka, Kazakhstan, Uzbekistan, Mongolia, Nepal and the Kyrgyz Republic. He gave talks in the planetaria of Amsterdam, Delhi, and Worli, at a grade school in Ahmedabad, and interviews for the new TV channel TARA in Ahmedabad and Mumbai.

Larsen invested considerable time training, coaching, employing, and tutoring students, especially the seven who are working or did work for Spacewatch: Natasha Carpenter, Nichole Danzl, Anne Descour, Arianna Gleason, Mike Read, Andrew Tubbiolo, and Ben Zuniga. Danzl and Gleason have discovered EAs, Centaurs, and TNOs, while Descour did a magnificent job of programming the IMPACT software interface. After obtaining her MS in Computer Science, she was hired by us as a full time Senior Systems Programmer. Read and Tubbiolo's work with computer hardware and electronics made it possible to modernize the data system at the telescope, and they are both now also trained solo observers. Larsen also helped Gleason create her poster for the internal LPL Conference in 2000.

Larsen hosted numerous visits by colleagues and fans of Spacewatch to the telescope, most notably to two groups from Raytheon Corp. and two groups of UA biologists. He gave a number of interviews for radio, TV, and news magazines. These included *The Arizona Daily Star's* science writer Jim Erickson and *Sky & Telescope's* Associate Editor Stuart Goldman on the topic of the discovery of the 17th moon of Jupiter, Jens Ramskov, Ph. D., of *Ingeniøren* (Engineering Weekly) of Denmark, Karelle Plummer, Jr. Exec. Producer of "Now Channel" in the UK, and Sofia Loverdou of "Greek Newspaper" on the topic of Spacewatch's rediscovery of the lost asteroid (719) Albert. Larsen was also interviewed by the University of Minnesota University Relations about naming minor planet (10172) after Prof. Roberta Humphreys. That was carried at least on the Tucson ABC-TV affiliate and published in *The Tucson Citizen, The Minneapolis Star*, and *The Minneapolis Tribune.* In addition, Larsen gave an email interview about NEAs to a freelancer, contributed to a press release by LPL's Agnieszka Przychodzen about Spacewatch research on Centaurs and TNOs, and gave an interview to Jorge Ianiszewski from *Circulo Astronomico* about Spacewatch's TNOs.

Larsen answered hundreds of questions from the general public received through access to our web site and contributed a piece to Benny Peiser's "CCNet" listserve on the asteroid impact hazard. Larsen's development of the Spacewatch web site (*http://www.lpl.arizona.edu/spacewatch*) was rewarded by awards from Key Resource, StudyWeb, and Scout Report Selection services.

Larsen also gave two talks at the U. S. Naval Academy in Annapolis, Va. and a colloquium at the Univ. of Minnesota. He is coaching a faculty member and midshipmen at the Naval Academy to observe asteroids with their small but modern telescope. As a successful graduate of University of Minnesota - Morris, Larsen was asked to reminisce about what their campus was like in the "dark ages" of 1985-1989. (His response included the fact that he had to walk 10 miles uphill to school each way in the snow.)

McMillan, Perry, Bressi, Scotti, and students Mastaler, Read and Tubbiolo, and Administrative Assistant T. M. Lane of Spacewatch spent considerable time communicating with and training an astronomer from the Ulaan Baatar Observatory in Mongolia. This effort is funded by our other grant from the AFOSR, F49620-00-1-0126 entitled "Spacewatch Survey for Asteroids and Comets". The purpose of this education is to develop the capability for astronomers in Mongolia to observe asteroids. This has been given a high priority by DoD/Pentagon.

McMillan gave video interviews for Phoenix commercial TV, UA News Services, the Tucson affiliates of NBC-TV and PBS-TV, and the RSK program of Sanyo Broadcasting Co. of Japan. He did an interview with reporter/still photographer Kazuya Nagase of Kyodo News of Japan. He contributed to press releases and interacted extensively with the press on the topics of Spacewatch's rediscovery of the long-lost asteroid (719) Albert and the Spacewatch discoveries of S/1999 J1 (a satellite of Jupiter) and 2000 WR106, the brightest known TNO other than Pluto. McMillan and Joe Montani hosted and assisted a still photography crew for *Worth Magazine* at the Spacewatch telescopes. McMillan also gave tours of the Spacewatch telescopes for participants of a Mars Conference, a meeting of chemists, an assemblage of UA Dept. Heads, an advisory board to the UA College of Science, the Japan Spaceguard Association, and (with Gehrels and Read) a United Kingdom Task Force on Near-Earth Objects. This latter helped that Task Force write a thorough and thoughtful report to Her Majesty's Government on the hazard of impacts by asteroids that was also well received internationally. McMillan's presentations at the Space Studies Institute in Princeton, NJ and the Colorado School of Mines in Golden, CO reached students and members of the general public in addition to professionals. With Mike Read he upgraded the Spacewatch web page, and granted permission for many organizations, including planetaria, to use images from the page for media productions. McMillan gave talks on Spacewatch to Prof. Steve Tegler's physics class at Northern Arizona University in Flagstaff, to the Saddlebrooke retirement community near Tucson, and a class of senior students at Tucson High Magnet School. McMillan also provided technical advice to two science fiction writers.

Scotti gave several public lectures in this time period, including the Annual Dinner Meeting of the Ottawa Centre of the Royal Astronomical Society of Canada in 1998 November, a guest presentation and question and answer session at Vail Middle School in 1999 May, two phone lecture and question and answer sessions with Edison High School (Fresno, CA), and a public lecture in 2000 April at the Pima Air and Space Museum.

Scotti's interaction with the press extended from phone interviews and conversations, to film interviews, to live radio call-in shows, magazine articles, and numerous web/e-mail related interactions, including several for stories in newspapers or web publications. These were mostly for the (719) Albert story, but there were also some on the impact hazard. He was interviewed on national TV in 1998 on the 1997 XF_{11} affair, and wrote an article on his discovery of that closely-approaching asteroid for *Sky and Telescope* magazine (Scotti 1998). Scotti did a radio interview on "Let's Talk Stars" on KTKT with David Levy on Sept. 12, 2000, a radio interview on KXAM (Phoenix) with Dr. Sky (Steve Cates) on Nov. 24, 2000, and a video interview for "Savage Planet". He was interviewed by Jim Erickson of *The Arizona Daily Star* for the (719) Albert story.

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