A LIVELY ELECTRONIC COMPENDIUM OF RESEARCH, NEWS, RESOURCES, AND OPINION

Astronomy Education Review

Volume 7, Feb 2008 - Dec 2008
Issue 1

An International Asteroid Search Campaign

Internet-Based Hands-On Research Program for High Schools and Colleges, in Collaboration with the Hands-On Universe Project

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Received: 10/17/07, Revised: 12/18/07, Posted: 03/03/08

The Astronomy Education Review, Issue 1, Volume 7:57-83, 2008

Abstract

The International Asteroid Search Campaign (IASC, fondly nicknamed "Isaac") is an Internet- based program for high schools and colleges. Within hours of acquisition, astronomical CCD images are made available via the Internet to participating schools around the world. Under the guidance of their teachers, students analyze the images with free software tools, searching for new asteroids and confirmations of near- Earth objects (NEOs). These discoveries are reported to the Minor Planet Center (MPC; Smithsonian Astrophysical Observatory, Harvard), which gives the students published recognition in its MPC circulars. To date, 36 new Main Belt asteroids have been found in one year, and 197 NEOs confirmed.

1. INTRODUCTION

The literature reveals several programs that provide high school and college students with the opportunity to conduct hands-on research in astronomy and astrophysics. In this article, a complete program is described, from acquisition of images to analysis by high schools and colleges, culminating in student-authored reporting of asteroid discoveries and near-Earth object (NEO) confirmations to the Minor Planet Center (MPC). The hands-on research and original student discoveries have been cited previously in professional publications (Miller et al. 2007a, 2007b; Pennypacker, Miller, & Canaday 2006).

Other programs have resulted in interesting science being undertaken by students. For example, the Goddard Space Flight Center provides software tools and an Internet portal for high school and college students. Students analyze data from the Rossi X-Ray Timing Explorer satellite (Lochner, Mitchell, & Pence 2006).

The Sloan Digital Sky Survey (SDSS) offers dataset releases to teachers and students. Structured Query Language (SQL) tools are in place to assist students in the retrieval and analysis of these data. Available to teachers is "a set of exercises that use these data to teach science from elementary school through introductory college" (Raddick 2006, 1). Another SDSS program entitled *The Galaxy Zoo* has 85,000 participants, exploring the distant Universe via the Internet. The goal is to classify images of one million galaxies (http://www.sdss.org/news/releases/20070808.galaxyzoo.html).

The Pisgah Astronomical Research Institute provides students in Grades 8–12 with the use of an Internet-accessible 4.6-m radio telescope (Castelaz et al. 2005). A visit to http://www.pari.edu shows that small optical telescopes are also available, as are instruments for monitoring cosmic rays, meteors, and earthquakes.

Stardust, the NASA interstellar dust and comet sample return mission to Comet Wild 2, features Stardust@home. Using a virtual microscope via the Internet, students search the aerogel collectors on board Stardust looking for these particles (Mendez et al. 2006).

By no means is the above list exhaustive. It represents only a sample of the growing number of Internet-based astronomical research programs available to students. It illustrates the extent and sophisticated nature of some of these programs, and the unprecedented hands-on research opportunities in astronomy and astrophysics available to students.

The development of high-speed Internet technology and retrieval systems for large datasets plays a key role in the delivery of these student programs. Prior to this development, hands-on research opportunities for students were more localized and only available to a limited number of enthusiastic and dedicated teachers and students who had to travel to the sponsoring institutions.

Although the non-Internet programs were clearly valuable, the inherent lack of scalability left thousands of eager students without access to such hands-on research opportunities. With the high-speed Internet access in most schools, this has changed. Programs and large astronomical datasets now have worldwide accessibility.

To design more scalable and accessible systems for teachers and students, the International Asteroid Search Campaign (IASC) was developed as an Internet-based hands-on research program. Established in August 2006, high school and college students from 55 schools in nine countries have participated, with new schools being added for each campaign. Using free software tools to analyze same-day CCD images, the students make original discoveries of Main Belt asteroids and confirmations of NEOs. These are reported to the MPC (Smithsonian Astrophysical Observatory, Harvard), where the students are recognized in the published MPC circulars (Pennypacker et al. 2007; Miller et al. 2007a, 2007b).

2. INTERNATIONAL ASTEROID SEARCH CAMPAIGN

The International Asteroid Search Campaign is centered at Hardin-Simmons University (HSU; Abilene, TX) and uses the Hands-On Universe (HOU) teacher network for its collaboration. Using the Internet and the educational delivery platform Blackboard Learning System, high school and college students download same-day astronomical CCD image sets. Each school participating in IASC has its own sets.

The image sets are taken using the 0.81-m and 0.61-m prime focus telescopes at the Astronomical Research Institute (ARI; Charleston, IL). Each set contains at least three images taken along the ecliptic and separated in time by approximately 60 minutes. Using the software Astrometrica (Aguirre 1997) and image sets from the night prior to their daily class session, the students find a plate solution for an 0.61-m image set and then analyze the three images in the set for unknown Main Belt asteroids. They do the same with an 0.81-m image set; however, they search instead for NEO confirmations.

If an unknown asteroid is discovered in one of the 0.61-m image sets, a report is filed with the ARI to obtain a follow-up set within seven days of the original discovery. These follow-up sets are required by the MPC as part of the discovery process. It is necessary to obtain sufficient astrometric positional data from the plate solution to calculate an accurate orbit.

After the original asteroid discovery and follow-up is obtained, a report is filed with the MPC. Upon validation of the report, the MPC recognizes the discovery and cites the students in its published minor planet circulars.

An 0.81-m image set is taken in an area of the sky where a previously observed NEO is thought to be currently located. The MPC needs a confirmation for recovery of the object. The students stack and analyze images from a set using Astrometrica. They carefully study the images through a blink process with the purpose of identifying the NEO and recording accurate astrometric positional data from the plate solution.

These data are sent to the MPC as part of the NASA Near-Earth Object Program. As with an original asteroid discovery, the MPC validates the data and cites the students in its published circulars.

The IASC is provided at no cost to the participating schools. It is a collaboration of Hardin-Simmons University, Astronomical Research Institute, Lawrence Hall of Science (Hands-On Universe, University of California at Berkeley), and Astrometrica.

2.1 30-Day Asteroid Search Campaigns: Organization and Structure

Three 30-day asteroid search campaigns are offered each academic year, in October, February, and April. Typically, 15 high schools and colleges participate in each of the campaigns. One month prior to a campaign, invitations are sent to interested high schools and colleges. Those schools accepting the invitation are set up on the educational delivery platform Blackboard Learning System at Hardin-Simmons University (Figure 1).

During the month prior to the campaign, teachers at each of these schools download the software Astrometrica, along with a set of instructions and practice image sets. With online guidance from HSU staff, they learn how to use the software to find a plate solution, conduct an automated moving object search, and use the overlay and blink utilities to conduct a manual deep image search.

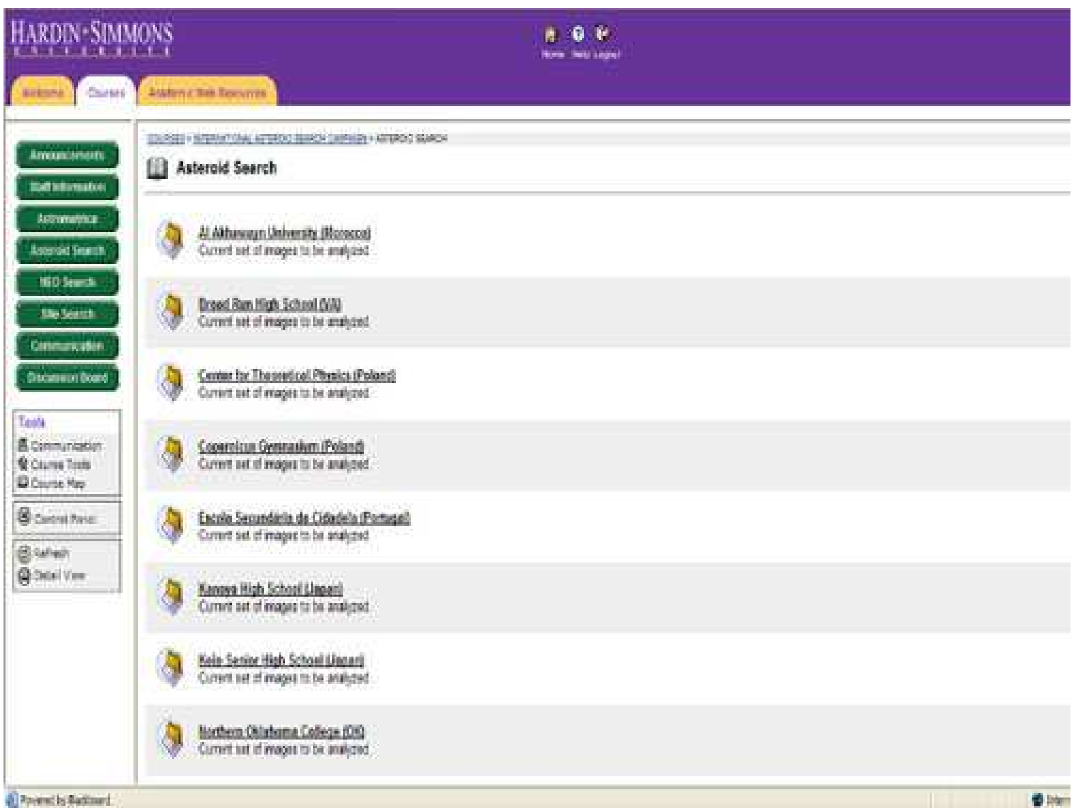

Figure 1. Folders are set up on HSU Blackboard for schools participating in a 30-day asteroid search campaign. (Click here for a larger image)

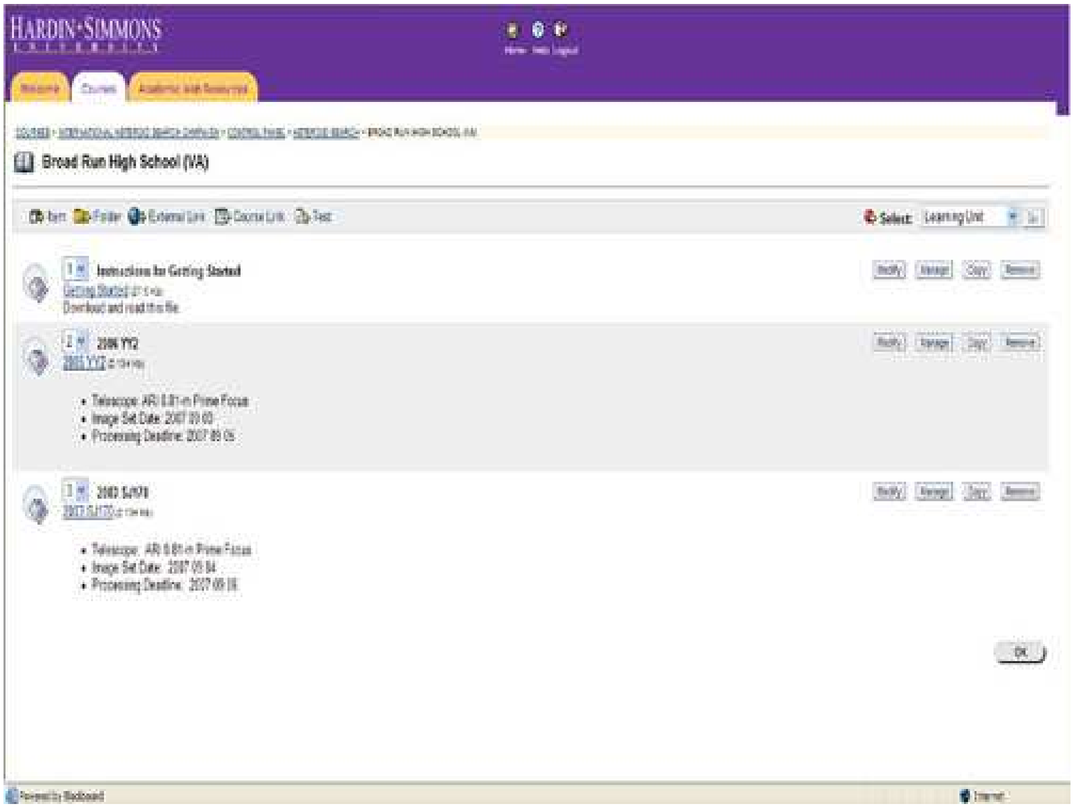

Figure 2. Image sets are uploaded into each of the school folders ready to be downloaded and analyzed by students. Each school receives it own image sets. (Click here for a larger image)

Image sets along the ecliptic are taken the night before, using the 0.61-m prime focus telescope at the ARI (see Figures 3 and 4). These sets contain at least three CCD (FITS) images spaced over a 60-minute period so that motion of any Main Belt asteroids can be seen in either an automated or a manual moving object search.

The morning after the images are taken, they are prescreened by HSU staff to ensure that they represent good data and that Astrometrica can find an accurate plate solution using no more than three iterations. Image sets not meeting these criteria are rejected for use in the asteroid search campaign. Almost certainly, the reason schools continue to participate is that the quality of the ARI data and the prescreening allow the students to work successfully and relatively free of data-processing pitfalls.

One important note is that the prescreening does not include identifying image sets with asteroid discoveries. The discoveries are made only after the students conduct their analyses using Astrometrica.

Although prescreening is labor intensive, it is absolutely essential for continued growth of the program. It may be that automated tools can be brought to bear on image prescreening, but for now, IASC is person-power-limited as to how many images can be provided to schools while maintaining the quality of the program.

After prescreening, the images are placed into a single zipped file (i.e., one image set) and uploaded to the schools' Blackboard folders (Figure 2). The sets are not shared. Each school receives its own sets. A maximum of five sets are provided to each school per week. The point is that schools can make their own discoveries and have ownership of, and responsibility for, these data, a very exciting and rewarding experience.

Figure 3. The 0.81-m (F/4.60) prime focus telescope at ARI (Charleston, IL) used for the IASC search campaigns.

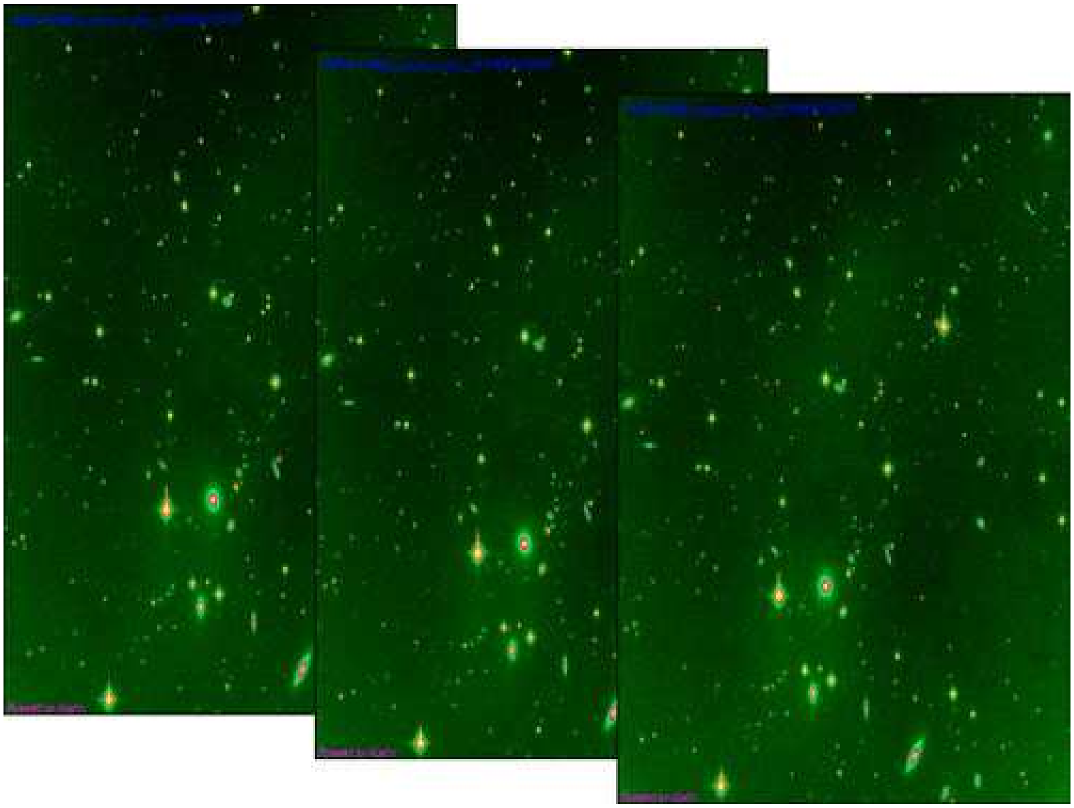

Figure 4. A sample of three images, separated in time by ~60 minutes, makes up one image set.

Under the direction of their teachers, who have integrated the asteroid search campaign into their curricula, the students download and unzip the image sets. They use Astrometrica to conduct the analysis within 48 hours (Figure 5). The image sets not analyzed by a school within that time period are downloaded and analyzed instead by a school designated as the backup site.

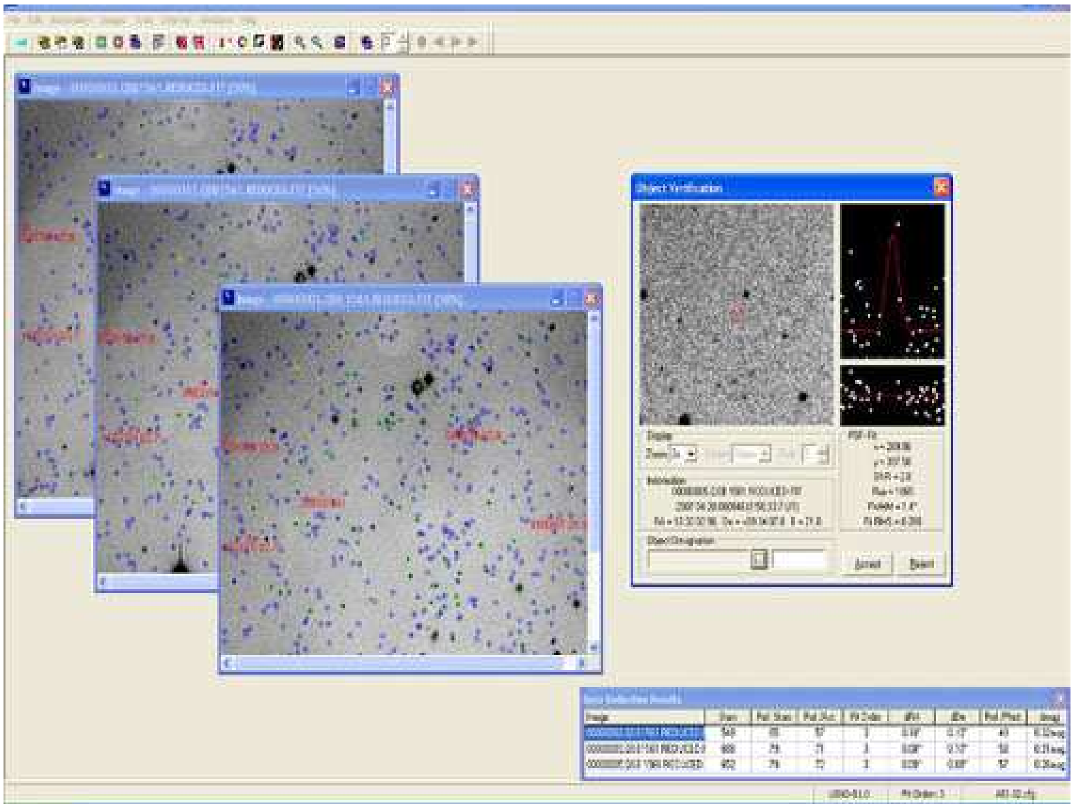

Figure 5. Shown is a typical analysis screen using Astrometrica. The automated moving object utility searches the three images in one image set for asteroids and compares the detected asteroids with the orbital dataset from the Minor Planet Center. (Click here for a larger image)

Astrometrica generates a report in the format required by the MPC. The finished reports are e-mailed to HSU, where they are checked for accuracy. Using MPChecker at MPC, HSU staff verify the asteroid discoveries reported by the schools (i.e., shown not to be within the MPC's most recently updated minor planet dataset).

After a few sessions, students at a participating high school or college typically become quite good at detecting actual asteroids, distinguishing them from false events. As a school begins an asteroid search campaign, it is not unusual for the students to report hot pixels, reflections, or bad pixels as an asteroid discovery. On occasion, the students will fail to update the MPC minor planet dataset before using Astrometrica, so known asteroids not in the older dataset show up as a discovery.

The MPC requires follow-up image sets and measurements of any discoveries. The follow-up must be taken within seven days to verify the discovery and obtain astrometric positional data sufficient to calculate an orbit. Validating the reports for discoveries ensures that the ARI will not expend valuable telescope time conducting the follow-up image sets on false events. HSU staff forward the validated reports to the ARI with a request for the follow-up. The follow-up image sets are taken and again uploaded to Blackboard for the students to analyze using the procedure outlined earlier. With validation of follow-up image sets identifying the asteroid discovery a second time, the ARI sends a final report to the

MPC. The MPC reports the discovery and cites the students in its published minor planet circulars.

2.2 NEO Confirmation Campaigns

Two 60-day NEO confirmation campaigns are offered each academic year: October–November and February–April. Typically, 10 high schools and colleges participate in each of the campaigns. These schools have participated in previous 30-day asteroid search campaigns, so their teachers are fully knowledgeable in the use of Astrometrica. In contrast to an asteroid search campaign, an NEO confirmation campaign is not looking for new asteroids, although on occasion, they are discovered, as are comets. The purpose of an NEO campaign is to recover or confirm a previously observed NEO. From this confirmation, accurate astrometric positional data are reported to the MPC, which uses them to update orbits for the potentially Earth-threatening NEOs.

The NASA Near-Earth Object Program is an ongoing search for asteroids and comets at least 140-m in diameter with perihelion distances within 1.3 A.U. from the Sun. These Earth-crossing objects pose an impact hazard with catastrophic results for life on Earth (e.g., the Chixulub/KT Boundary impact by a 10-km object believed to have caused the planetwide extinction of the dinosaurs). The ARI is funded to work with the MPC to confirm NEO discoveries as part of the NASA program. Schools participating in the 60-day NEO confirmation campaigns are providing the MPC with valuable data in the search for such asteroids and comets.

The ARI uses its 0.81-m prime focus telescope to search for NEOs. To observe objects down to the 21st and 22nd magnitude, an image set is taken over a 60-minute period that can contain 18–24 short-exposure images. Using Astrometrica, the students stack these images to conduct a manual deep image search for the NEOs. For the fainter NEOs, the students stack and track the images. That is, Astrometrica allows students to stack images with offsets at the suspected asteroid movement across the images, so all the light from the asteroid is concentrated into a few pixels instead of being spread out over a large number of pixels and not visible in the background.

Whereas schools participating in the 30-day asteroid search campaigns have 48 hours to analyze their image sets, the schools in the NEO confirmation campaigns must sometimes complete the analysis within 12 hours and report their astrometric measurements and positional data directly to the ARI. The ARI validates the data and then files a report with the MPC. Confirmations are published in minor planet circulars, again with citations for the students.

2.3 Supernovae Search Campaigns

In an effort to expand IASC to include student discoveries of other transient events such as supernovae (SNe) and active galactic nuclei (AGN), a 60-day pilot SNe search campaign was introduced in October–November 2007. Teachers and students from three high schools participated in this campaign.

Working under the HOU teacher resource agent Harlan Devore of Cape Fear High School (Fayetteville, NC), the participating teachers and students were trained in how to search for and identify supernovae. In future campaigns, they will learn to construct light curves of ongoing supernovae.

An SNe search campaign is more complex than either an asteroid search or NEO confirmation campaign. This type of search involves better identification and elimination of false events and better communications among the participating schools. Images are taken of clusters of galaxies (typically Abell clusters) using the ARI 0.61-m prime focus telescope. These are compared with a reference library of images of these same clusters taken three to six months earlier. It is not unusual for 50 of these image sets to be analyzed between supernova discoveries.

One of the false events that arises because of this particular cadence is an AGN in the core of a galaxy. This event can easily be confused with a supernova located toward the galactic core. To distinguish between the two, either a light curve needs to be constructed over time or a spectrometer used to examine the light. Currently, only the light curve method is available to the schools participating in the IASC SNe search campaign. Ideally, the search would compare reference images taken within two weeks to help suppress the detection of an AGN event.

Software for future SNe search campaigns is being developed using the Interactive Data Language (IDL) from Research Systems (RSI; Boulder, CO), a Fortran-like interpretive language used in data analysis and image processing. The Goddard Space Flight Center has a library of IDL utilities that enable reasonably rapid development of this software, with little concern for detailed pixel-indexed routines. However, IDL runs slowly on large images, so some of the key loops will be optimized in C or other faster programming languages. The software will measure the median photometric ratio between the two images (i.e., the current image and the earlier reference image). Then, it will perform an optimal image subtraction (Alard 2000) of the two images. From the subtraction, a list of SNe candidates will be identified for the students to study using a manual deep image search on the original two images (Figure 6).

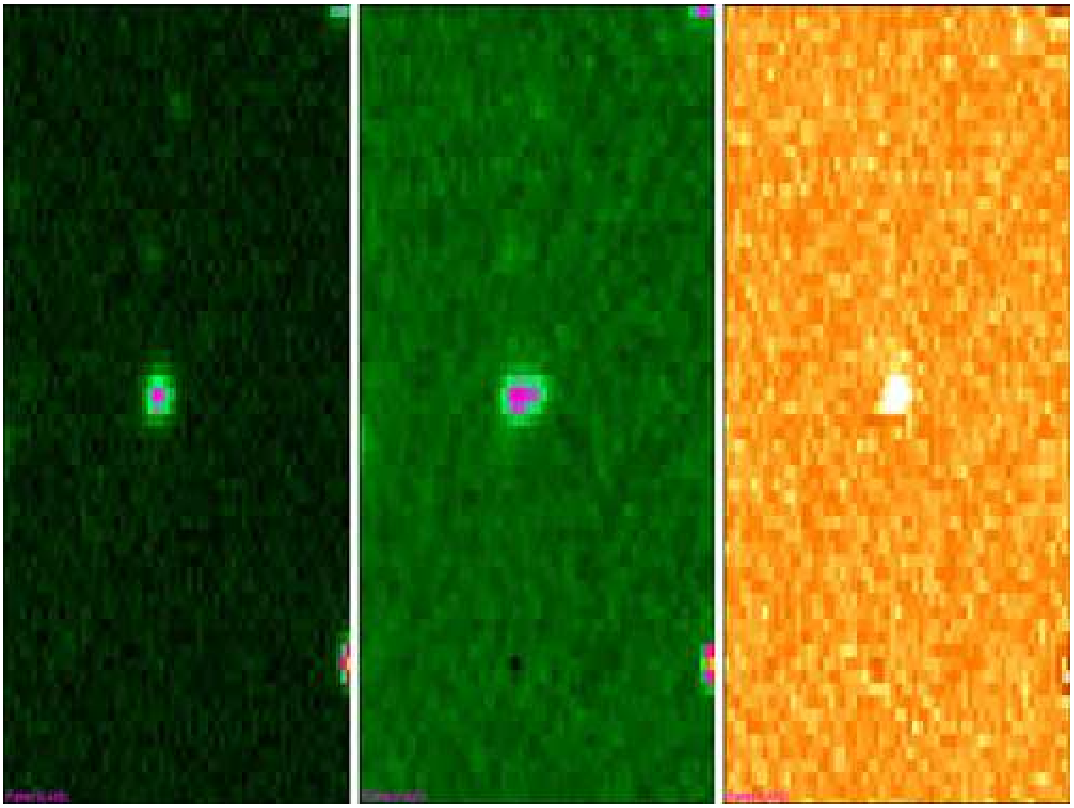

Figure 6. Discovery of SN 2006al using images from the Astronomical Research Institute and an optimal image subtraction by J. Patrick Miller. The discoverers are Robert E. Holmes, Jr., ARI, and Harlan Devore, Cape Fear High School (Fayetteville, NC).

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3. THE COLLABORATION

The International Asteroid Search Campaign is provided at no cost to the participating schools. It is a collaboration of Hardin-Simmons University, Astronomical Research Institute, Lawrence Hall of Science (Hands-On Universe), and Astrometrica. Each of these groups has science education as one of its key themes, so this is a natural collaboration that generates strong mutual support and delivers a quality Internet-based hands-on research program for the students at the participating schools.

3.1 Hardin-Simmons University

Hardin-Simmons University is the originating and coordinating center for the IASC. The program is directed by J. Patrick Miller, associate professor of mathematics. He handles the prescanning of image sets before uploading to Blackboard, and the design of the analysis methodology used by the students as they search for original discoveries. Jeffrey W. Davis, undergraduate in the HSU Honors Program, handles the validation of new asteroid discoveries and fields the multitude of questions from teachers and students during the course of the campaigns. Also assisting in the prescanning and report validations is Dominic Juliano, HSU undergraduate.

3.2 Astronomical Research Institute

The ARI is a 501(c)(3) not-for-profit corporation performing research in astronomy and public outreach programs for student-based research. The primary goal is to encourage students to think like scientists as they explore the Universe. The ARI works with teachers and students to provide hands-on research projects that lead to actual discoveries.

In addition, the ARI is generously funded to work with the MPC to confirm NEO discoveries as part of the NASA Near-Earth Object Program (NASA Grant No. NNX07AR16G). During an evening, hundreds of images are taken using the 0.81-m and 0.61-m prime focus telescopes in support of the NASA program and the IASC search campaigns.

Robert E. Holmes, Jr., is the director of the ARI. Much time at these telescopes is required to take images that are then subsequently uploaded to Blackboard for the participating students to analyze. These images are provided to the asteroid search campaigns, NEO confirmation campaigns, and the pilot SNe search campaigns. Without his dedication and devotion to student hands-on programs in astronomy, there would be no IASC.

3.3 Lawrence Hall of Science (Hands-On Universe)

The Lawrence Hall of Science (LHS) is a resource center for preschool through high school science and mathematics education. It is a public science center with hands-on activities for all ages.

Located at the University of California, Berkeley, the LHS is the educational center for Hands-On Universe, an outreach program enabling students to investigate the Universe while applying tools and concepts from science, math, and technology. Using the Internet, HOU participants worldwide request observations from automated telescopes, download images from large archives, and analyze these images with the aid of user-friendly processing software. HOU is a collaboration of the LHS, TERC, Inc. (Cambridge, MA), Adler Planetarium (Chicago, IL), and Yerkes Observatory (Williams Bay, WI). It includes a network of educators and astronomers from all over the world.

3.4 Astrometrica

Astrometrica is an interactive software tool for scientific-grade astrometric data reduction of CCD images. Among its numerous capabilities, it provides automatic image calibration, blinking with automatic image alignment, zoom and magnification, automatic reference star identification, automatic moving object detection, plus track and stack.

Software engineer and longtime amateur astronomer Herbert Raab (Austria) is the author of Astrometrica. He wrote the original version in early 1993. In the years since, thousands of astrometric positions of NEOs, comets, and asteroids have been recorded. The most recent version is dated November 2005 and is available for download at http://www.astrometrica.at.

4. TEACHER PARTICIPATION

4.1 Teacher Training Workshops

The key to success for any IASC campaign is the support of the teachers as they implement campaigns in their curricula. As a result, it is important that the teachers are fully trained in the use of Astrometrica before the start of any campaign.

The 30-day asteroid search campaigns require a plate solution of the three images in an image set, an automated moving object search, and a manual deep image search. Written training instructions and practice image sets are provided to the teachers one month prior to the start of an asteroid campaign. Hardin-Simmons University staff provide online assistance to the teachers as they install, configure, and learn to use Astrometrica.

Some on-site training workshops are provided to groups of teachers. Workshops are presented at Yerkes Observatory during the annual meeting of Hands-On Universe and at the international site of the annual meeting of Global Hands-On Universe (e.g., National Astronomical Observatory of Japan [Tokyo]; Observatoire de Haute [Provence, France]). Using Skype and a translator, a workshop was conducted with teachers attending the annual meeting of China Hands-On Universe (Beijing).

Workshops are given to the astronomy faculty from community college districts and to high school teachers attending professional meetings (e.g., Space Exploration Educators Conference, NASA Johnson Space Center). When possible, the teachers attending these workshops are given new image sets taken the previous night, and they use these to practice their newfound Astrometrica skills.

At one workshop conducted at the 2007 Big Country Math & Science Symposium (Region 14, Texas), two high school teachers discovered Main Belt asteroids and received a citation in the minor planet circulars. During the weeklong 2007 annual meeting of the Global Hands-On Universe (NAOJ, Tokyo), four asteroids were discovered and reported to the MPC.

4.2 Teacher Professional Development

In every search campaign, teachers and students from some schools successfully participate and make a number of original discoveries. The teachers from these schools are invited to return to future IASC campaigns, which include NEO confirmations and SNe searches. These campaigns are considerably more complicated than an asteroid search and require additional software and training.

For the NEO confirmation campaigns, there is no prescreening of the images by the HSU staff as there is for the asteroid search campaigns. The teachers must learn to use the stack and track capabilities of Astrometrica. They must also learn how to build a third-order plate solution in order to make accurate positional measurements.

Instead of prescreening and uploading image sets to Blackboard, a written assignment is provided in the folders of the participating schools. With the assignment in hand, the students go directly to the ARI FTP site, where they download the designated images. They handle all pitfalls of data processing, including culling of bad data, building image stacks, and dealing with problem stacks for which Astrometrica cannot find a third-order plate solution.

As with the asteroid searches, the teachers are provided with written materials and online training for the NEO confirmation campaigns. Because they have already used Astrometrica for asteroid searches (i.e., automated and manual deep image utilities), this training supplements their knowledge. More important, it adds further to their understanding of astronomical research methods, which is necessary for hands-on research in their classrooms.

For SNe search campaigns, these have not been fully implemented into IASC but continue in the pilot mode. The long-term plan is to incorporate these as ongoing IASC search campaigns. In October–November 2007, three schools participated in the first pilot campaign. They worked with Harlan Devore of Cape Fear High School to learn how to conduct a SNe search. He served as the master teacher (HOU teacher resource agent) leading the training of the other teachers in the use of the software packages CCDSoft and The Sky6 Professional Edition (Software Bisque; Golden, CO).

In addition to image sets of Abell galaxy clusters provided by the ARI for SNe searches, the teachers had to download and use images from the Sloan Digital Sky Survey (SDSS). The ARI did not have a complete library of reference images, resulting in the need to use the SDSS images. This required the teachers to learn image alignment and scaling, additional skills in research methods.

Future SNe search campaigns will include training in differential photometry so that teachers can construct light curves of ongoing SNe events. The teachers will learn the use of the software package of astronomical research utilities provided by Hands-On Universe (http://www.handsonuniverse.org).

In summary, teachers join IASC for the first time by having their students participate in the asteroid search campaigns. These campaigns are designed to make nominal use of Astronomica to analyze prescreened, problem-free image sets. After a successful asteroid search campaign, the teachers can proceed to the more difficult NEO confirmation campaigns. These make extensive use of Astrometrica to analyze image sets that are not prescreened or necessarily problem free.

As a third step, and when fully implemented, the teachers can proceed to the SNe search campaigns. These campaigns introduce the teachers to new, advanced research methods and software, including CCDSoft, The Sky6, and HOU research utilities.

Teachers who successfully complete all three of these campaigns will be highly skilled in the use of

- Astronomical research methods
- Software packages for analysis
- Astronomical datasets

These teachers will no longer have a need for IASC. They will be able to conduct their own hands-on research programs in their classrooms. Their students will be able to directly access and analyze datasets.

4.3 Use in the Classroom

How IASC is used in the classroom is left in the hands of the participating teachers. Some teachers plan 30-day or 60-day units around the program, in which all students work together to analyze the image sets. Other teachers assign the analysis to a small group of motivated students with a keen interest in astronomy. Introductory astronomy courses at colleges assign the image analysis as a major lab project.

The first goal of IASC is to provide teachers with a high-quality Internet-based tool that delivers hands-on research to their classrooms. The tool is designed so that students can successfully make original astronomical discoveries.

It is not the goal of IASC to require teachers to integrate the program, in any particular manner, into their curricula. The task of curriculum design is left to the teachers regarding how they want to use IASC.

The second goal is to provide a professional development pathway for the participating teachers. As outlined in section 4.2, Teacher Professional Development, IASC provides teachers with such a pathway starting with asteroid searches, then NEO confirmations, and finally, pilot SNe searches. Teachers successfully following this pathway will develop their professional research skills. They will be master teachers qualified to conduct standalone, hands-on astronomical research programs in their classrooms.

4.4 How to Participate

High school and college teachers are encouraged to apply as participants in future IASC campaigns, searching for unknown asteroids and making NEO confirmations. Annually, there are three 30-day asteroid search campaigns conducted in February, April, and October, with 15 schools participating in each. In addition, two 60-day NEO confirmation campaigns are conducted in February–April and October–November, with 10–15 schools per campaign.

If you are a teacher interested in having your school participate, contact the following person either in writing or by e-mail. Include your name and e-mail address, plus the name and address of your school:

J. Patrick Miller
Department of Mathematics
Hardin-Simmons University
Abilene, TX 79601
pmiller@hsutx.edu

An active list of interested teachers is maintained by IASC. Invitations are sent one month prior to the start of a new campaign.

A school needs access to PC-based computers with the hardware requirements listed below. For networked computers, it is necessary to have administrative rights to install, configure, and use Astrometrica. Additionally, it is recommended that there be at least one computer for every three students:

- PC with 350 MHz CPU, 64 MB memory, running 32 bit Windows (Windows 95, 98, 2000, ME, NT, or XP), or
- PC with 500 MHz CPU, 128 MB memory, running Windows NT, XP, or 2000 recommended

A teacher who has not attended an IASC training workshop is required to undergo online training during the month prior to the start of a new campaign. On Blackboard at Hardin-Simmons University, Astrometrica is provided for download with an installation guide. Also provided are practice image sets and written training instructions.

With the online assistance of HSU staff, the teacher learns to use Astrometrica to produce a plate solution of the three images in an image set, and to conduct an automated moving object search and a manual deep image search. The end result of an image set analysis is the MPC report summarizing the positional data of asteroids within the set. The report must be absolutely accurate (i.e., 100% accurate MPC report = mastery of Astrometrica).

Following the written training instructions, the teacher makes a first attempt at producing an MPC report. This first report is e-mailed to HSU staff, who critique it. Suggestions are offered for improvement, and the process is repeated until the teacher submits a 100% accurate report using a new practice image set. Typically, the training requires no more than four hours of computer time to complete.

For student success in IASC, it is critical that a teacher be fully trained in the use of Astrometrica and the preparation of MPC reports before a campaign starts. The teacher’s job is then to train the participating students, ensuring that their analyses and MPC reports are accurate prior to submitting them during an ongoing campaign.

During a 30-day search campaign, a school will receive up to a total of 20 image sets (five sets per week). Each set must be processed within 48 hours, allowing sufficient time to complete the necessary seven-day follow-up image set to confirm the discoveries.

Left to the discretion of the teacher is the task of implementing IASC into the curriculum and organizing the students to conduct the analysis. Some teachers assign one or two students to IASC as a special research project. Other teachers have 20 students working on IASC image sets as part of a planned monthlong class activity.

In effect, IASC is an educational outreach program that serves the teacher as a flexible Internet-based resource. It allows a teacher to conduct hands-on scientific research with original astronomical discoveries made by students. The teacher can use the program in whatever ways best fit the classroom and curriculum.

5. STATISTICS

The first year of IASC ran from October 2006 through May 2007. A total of three 30-day asteroid search campaigns were organized. In these campaigns, 32 schools participated from the United States, Poland, and Russia.

Table 1. Distribution of the Participating Schools (October 2006–May 2007)		
Type of Schools	**# of Schools**	**# of States**
High Schools (U.S.)	19	13
High Schools (Intl.)	4	2
Community Colleges	6	3
Universities	3	2

Table 2. Locations of the Participating Schools (October 2006–May 2007)	
Types of Schools	**Locations**
High Schools (U.S.)	AK, AZ, CA, IL, KS, MA, NC, NH, OK, RI, TX, UT, VA
High Schools (Intl.)	Poland, Russia
Community Colleges	NC, OK, TX

At the time of this writing, the second year of IASC is under way for October 2007 through May 2008. There are three 30-day asteroid search campaigns, two 60-day NEO confirmation campaigns, and one 60-day pilot SNe search campaign. Nine countries are participating: China, Germany, Italy, Japan, Morocco, Poland, Portugal, Russia, and the United States (see Figures 7, 8, and 9).

Table 3. Distribution of the Participating Schools (October 2007)		
Type of Schools	**# of Schools**	**# of States**
High Schools (U.S.)	9	8
High Schools (Intl.)	7	5
Community Colleges	3	3
Universities (U.S.)	2	2
Universities (Intl.)	2	2

Table 4. Locations of the Participating Schools (October 2007)	
Types of Schools	**Locations**
High Schools (U.S.)	AK, CA, IL, NC, NH, UT, VA
High Schools (Intl.)	Germany, Italy, Japan, Poland, Portugal
Community Colleges	NC, OK, TX
Universities (U.S.)	TX
Universities (Intl.)	Morocco, Japan

During the first year of IASC, the following student discoveries were made and reported to the MPC for official recognition as published in the minor planet circulars:

Table 5. Student Discoveries (October 2006–May 2007)	
Object	**# Discovered**
Main Belt Asteroids	36
NEO Confirmations	197
Comet Confirmations	1

Figure 7. Barbara Dluzewska and her students at Czacki High School (Poland) point to an asteroid discovery they made during a 30-day asteroid search campaign (April 2007).

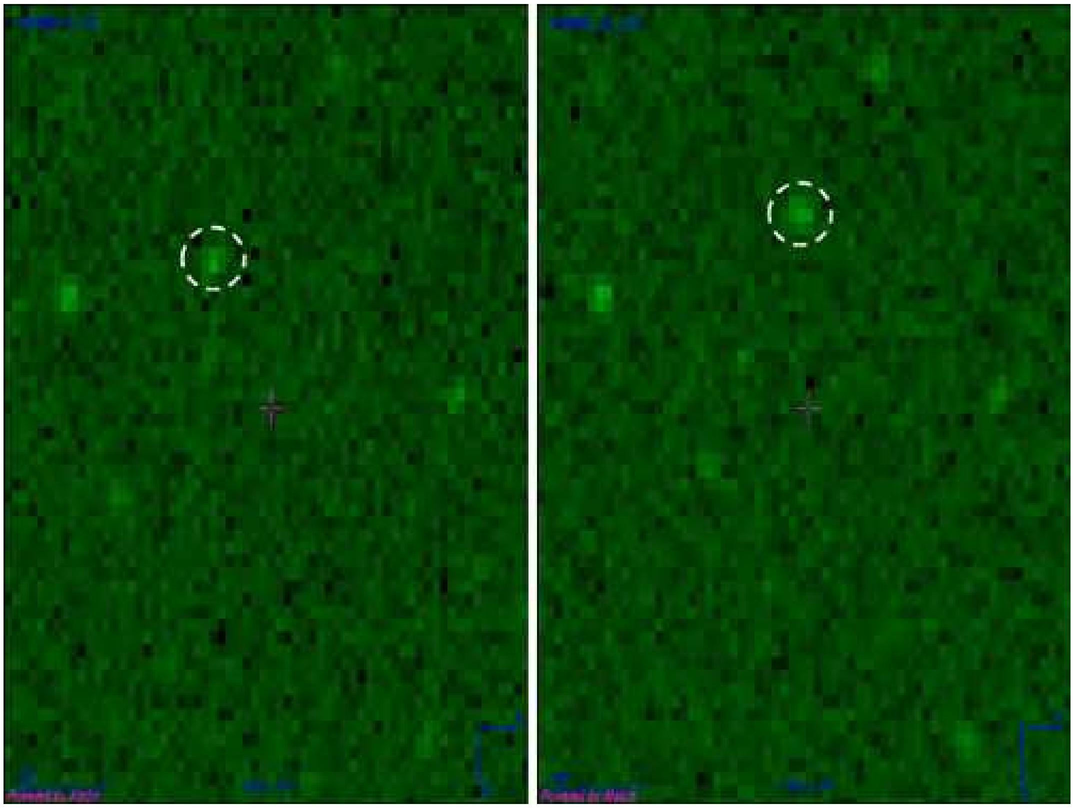

Figure 8. An asteroid discovery by students at Meredith College (Raleigh, NC) in February 2007.

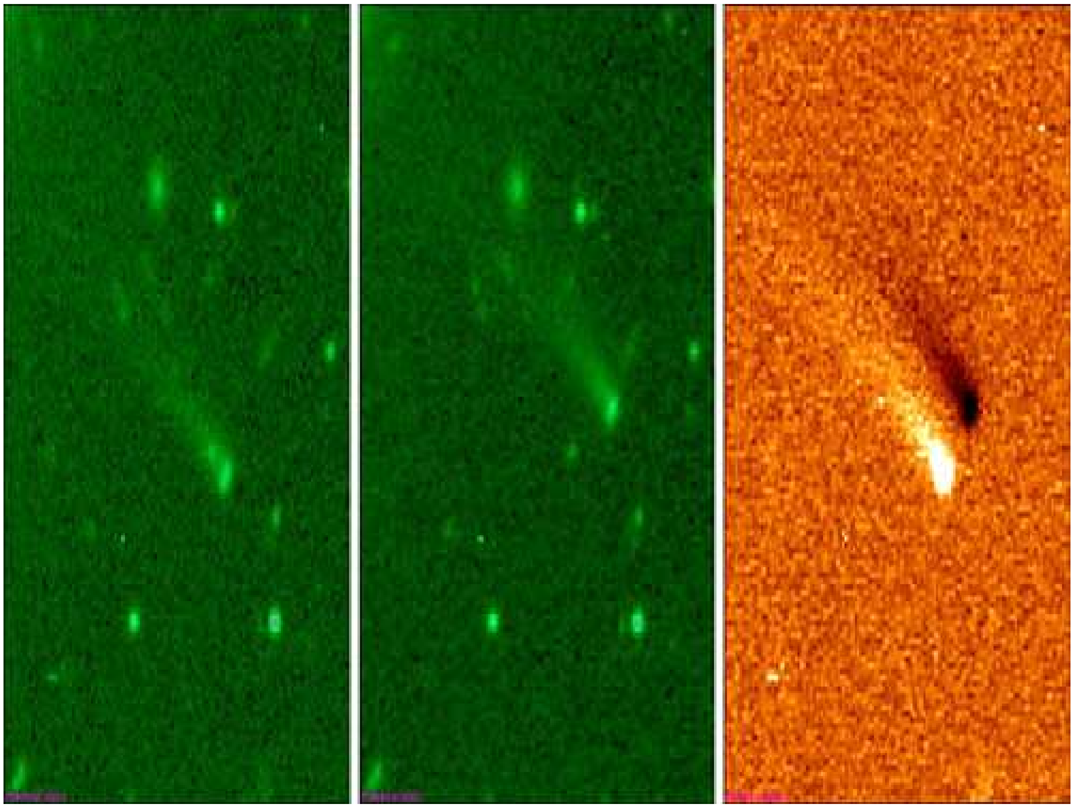

Figure 9. A comet confirmation by students at Brookhaven College (Farmers Branch, TX) in April 2007.

6. LESSONS LEARNED

6.1 Appropriate Combinations of People, Instruments, and Software

During the first year, a number of lessons were learned from the administration of IASC that brought it from a possible failure to a complete success. IASC began with a 30-day pilot asteroid search program in October 2006. Students from only five schools participated as the methodology and administrative procedures were tested and refined.

Image sets taken with the 4-m Victor M. Blanco telescope at the Cerro Tololo Inter-American Observatory (CTIO; Chile) were generously provided by Dr. R. Chris Smith (National Optical Astronomy Observatory). These sets were from ESSENCE (The W Project), a professionally directed search for supernovae within the redshift range $0.15 \leq z \leq 0.75$ (http://www.ctio.noao.edu/wproject).

Many original discoveries of asteroids were found in the ESSENCE image sets, but it was difficult to meet the seven-day follow-up image set requirement of the MPC to confirm the discoveries. The use of professional instrumentation is scheduled months in advance. It is not readily available to handle impromptu requests for follow-up image sets needed to confirm the discoveries.

To handle the follow-up requests, IASC approached the Astronomical Research Institute to use its 32" prime-focus telescope. In some cases, the asteroids were too faint to be detected with this smaller instrument. The positional data were measured using the software Aladin (Bonnarel et al. 2000), and in some cases, these data were insufficient to construct accurate ephemeredes. As a result, no asteroid discoveries were confirmed in the October 2006 pilot program. This suggested that the IASC concept of an Internet-based tool for original astronomical discoveries might be more difficult to build and be successful than originally thought.

In the February 2007 and April 2007 asteroid search campaigns, only the 32" prime-focus telescope at ARI was used for image sets. It was available for both the initial sets for the original discoveries and the follow-up sets for MPC confirmations. The 4-m CTIO telescope had been scheduled for other research and was not available to support IASC.

Astrometrica was introduced to handle the image set analyses and measurement of positional data. These changes proved quite successful and resulted in 36 asteroid discoveries and 197 NEO confirmations, all by students. An additional 35 asteroid discoveries were made by students in October–November 2008.

The right combination of instruments and software was the key to success of IASC. This combination made it possible for the Internet to serve as a tool for students to make original astronomical discoveries.

6.2 Limitations Due to Staff and Data

During the first year, it was learned that the number of schools that can participate is limited by two factors: (1) number of HSU staff to provide online services to the schools, and (2) number of available image sets per week.

The morning after image sets are taken, the HSU staff prescreen them. This is to ensure that the sets contain valid data (i.e., good images) and that Astrometrica can find an accurate third-order plate solution using no more than three iterations. After passing the prescreen tests, the images are placed into a single zipped file and uploaded into the schools' Blackboard folders, with each school receiving its own image sets. It may be that some wrapper scripting software can undertake aspects of the interactions with Astrometrica to ensure that good data get to the teachers and students. This would remove the bottleneck of image validation.

Although the prescreen is time intensive for HSU staff, it provides validated data to the schools that will work successfully in Astrometrica. A school may not find any asteroids within one of its image sets, but the set can be successfully analyzed by the students, and that is the key point. The HSU staff also review the MPC reports, ensuring that they are accurate and that any claims of new discoveries are correct. They work closely online with the schools during the first 10 days of a 30-day asteroid search campaign, helping them to fine-tune their skills in using Astrometrica and producing accurate reports.

It is time intensive to make certain that the image sets can be analyzed and that the schools understand how to produce accurate MPC reports from that analysis. However, to ensure the quality of the program and the overall experience of the students as they make original discoveries, this time-intensive attention to the data and students is essential.

Of course, the number of image sets available to the schools will limit the number of schools that can participate. At the present number of HSU staff members and numbers of image sets (at most five sets per school per week), IASC can serve 75 schools per year: 45 schools in three 30-day asteroid search campaigns, and 30 schools in two 60-day NEO confirmation campaigns. If IASC expands to include two 60-day SNe search campaigns, an additional 20 schools can be served, for a total of 95 per year. With some modest funding for student assistants at HSU, IASC could be scaled up. In particular, other telescopes may become available, both at ARI and other collaborating observatories, so IASC could meet growing demands for discoveries.

6.3 Large Sky Survey Educational and Public Outreach Programs

The lessons learned in IASC are applicable on a grander scale to the large sky surveys developing educational and public outreach (E/PO) programs that incorporate hands-on research projects for thousands of schools. PanSTARRS, SkyMapper, LSST, and VISTA are examples of such surveys. One day, these surveys will have E/PO programs that will provide outreach services to tens of thousands of students.

Should these programs be designed for students to make original discoveries, there must be the right combination of instruments and software that permits them to successfully follow through and complete their research projects. Should these programs aim to have students learn the research methods necessary to conduct their projects, there must be sufficient staff to answer their questions and data for them to analyze.

IASC can be a pathfinder for future instruments and campaigns. If a school participates in an asteroid search campaign, an NEO confirmation campaign, and perhaps a future SNe search, the teacher will be able to run an astronomy research program independently of IASC. That teacher could easily adapt to any of the E/PO programs offered by the large sky surveys and access the professional datasets, archived and available to the public.

7. FUTURE RESEARCH

IASC offers an ideal opportunity to study the effects of the program on the participating teachers and students. For example, the following important questions need to be addressed:

- How effective is the International Asteroid Search Campaign in changing the attitudes of the students towards science?
- How effective is IASC in teaching students scientific research methods?
- How effective is IASC in providing a hands-on research program for the teachers to integrate into their curricula?
- How effective is IASC in training teachers to integrate other E/PO programs into their curricula or to build their own research programs for their students?

Surveys to address these questions are now being developed for implementation starting with the three campaigns to be held February–April 2008.

A pre- and postsurvey for the students has been drafted to investigate the effectiveness of IASC in changing their attitudes toward science. In its final form, it will be deployed through Blackboard and become a standard component of all the search campaigns. This survey is a modification of an online article entitled "Survey of Attitudes Toward Astronomy" by Michael Zeilik (University of New Mexico). Refer to Figure 10 (see Note 1) and the online reference at http://www.flaguide.org/tools/attitude/astpr.php.

Click here to access Figure 10 in PDF.

Figure 10. A draft version of the presurvey and postsurvey to be used to assess the effectiveness of IASC in changing students' attitudes toward science.

A second survey has been drafted that obtains feedback from the teachers regarding the effectiveness of IASC in meeting their curricular needs. Also addressed will be feedback on how IASC can be improved to provide better educational outreach service in support of teachers who want to implement hands-on science research in their classrooms.

8. CONCLUSIONS

The International Asteroid Search Campaign is an Internet-based educational outreach program that brings hands-on science directly into high school and college classrooms. Under the direction of their teachers, the participating students have successfully discovered new Main Belt asteroids and confirmed both near-Earth objects and comets.

The students receive official published recognition for their discoveries by the MPC under the auspices of the International Astronomical Union. Some of their discoveries contribute directly to the NASA Near-Earth Object Program, which is working to identify objects that are potentially threatening to Earth (i.e., objects posing an impact hazard).

In addition to asteroids and NEOs, IASC is testing other search campaigns, including supernovae searches. A 60-day pilot program, October–December 2007, is being tested with the hope of expanding this program to an ongoing IASC search campaign included with the existing ongoing asteroid search and NEO confirmation campaigns.

Under discussion are campaigns that would include searches for Kuiper Belt objects, active galactic nuclei, and comets. These campaigns would be designed with the goal of having the participating students receive official recognition for their discoveries, as is currently done with asteroid and NEO discoveries.

The long-term goal is to keep IASC as IASC but to change it from the International Asteroid to the International *Astronomical* Search Campaign, in which high school and college students continue to make discoveries. IASC will become an established ongoing Internet-based educational outreach program in which hundreds of schools and thousands of students will participate from all over the world.

Large sky survey telescopes such as PanSTARRS, SkyMapper, LSST, and VISTA come online over the next few years, with the goal of detecting tens of thousands of objects such as supernovae, active galactic nuclei, asteroids, NEOs, and exoplanet transits. In this environment, the International Astronomical Search Campaign will be even more exciting as it provides a well-established and time-tested infrastructure for education and public outreach—human support, communications, and follow-up by dedicated staff with a focus on serving the participating teachers and students.

9. ACKNOWLEDGMENTS

The authors wish to thank Vivian Hoette at the Yerkes Observatory (Williams Bay, WI) for her pivotal role in bringing the collaborators together, which led to the organization and establishment of the International Asteroid Search Campaign. Each summer, she organizes the weeklong annual Hands-On Universe meeting for public school teachers, university professors, and professional astronomers.

It was during this meeting in June 2006 that both the need and resources to satisfy that need were identified. This led directly to the establishment of the first IASC asteroid search campaign a few months later, in October 2006.

Over the past five years, Harlan Devore and students at Cape Fear High School (Fayetteville, NC) and Robert E. Holmes of the Astronomical Research Institute developed prototype Internet-based discovery programs for high school students. They developed methodologies in the search for asteroids, NEOs, and SNe, most of which were adopted for use in IASC.

Undergraduate students from Hardin-Simmons University—Jeffrey W. Davis, Holly Fidler, and Dominic Juliano—assisted in the testing of these methodologies for IASC and the development of online instruction sheets used by the participating students and schools. Jeffrey W. Davis and Dominic Juliano are managing the three 2007–2008 asteroid search campaigns. Undergraduate students from Jackson State University (Jackson, MS) also played an important role in the testing of the methodologies for IASC. These students are Tylvia Edwards, Sarah Francis, Martha Ragwar, Carey Smith, and Fran Smith. Dr. Mehri Fadavi, Department of Physics and Astronomy, is the adviser and mentor for these participating students (Figure 11).

Dr. Christopher L. McNair, dean of the Holland School of Science and Mathematics at Hardin-Simmons University, contributes both administrative support and resources that allow the International Asteroid Search Campaign to flourish and continue to grow.

Figure 11. Shown are students from Hardin-Simmons University and Jackson State University, who worked on the testing of IASC methodologies at the Lawrence Berkeley National Laboratory (University of California, Berkeley).

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Note

Note 1: Figure 10 URL: http://aer.noao.edu/auth/Millerfigure10.pdf

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