PHOTOGRAPHING THE EARTH
G324, The CAN DO *GeoCam* Payload

James H. Nicholson and Thomas J. O'Brien
Medical University of South Carolina
Carol A. Tempel
Charleston County School District

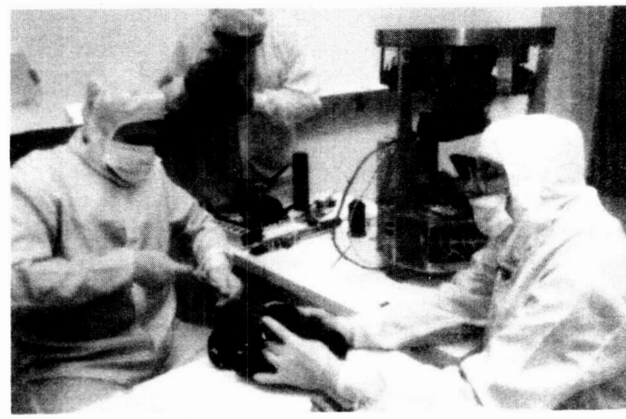
ABSTRACT

The flight of the Charleston County School District ***Can DO*** Project ***GeoCam*** payload on STS-57 was the climax of a decade long endeavor to bring the promise and excitement of the space program directly into the classroom. The payload carried four cameras designed to take high resolution photographs of the Earth under the direction of children operating the first ever student control room. During the course of the flight, the students followed the Shuttle's orbital tract, satellite weather images and selected a target list that was sent up to the crew each night as part of the execute package. Targets from this list, as well as ones chosen by the crew visually, resulted in the successful collection of photographic runs at many interesting sites on three continents.

EDUCATION AND EARTH OBSERVATION

Later this decade, earth sensing platforms will analyze Earth processes as part of a multi-national program, *Mission to Planet Earth*. By examining the past and monitoring the present it is possible to reach a deeper understanding of the Earth as a complex system. Photographic comparisons are powerful teaching tools, especially in the appreciation of change over time. By comparing transformation documented in earth viewing photographs, changes that occurred in our lifetime can be observed. Photographic documentation of global change makes it more immediate and real.

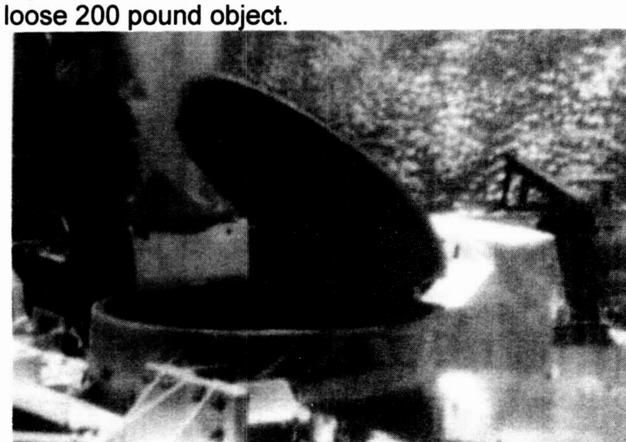
NASA and other agencies are concerned about the projected shortage of scientists and technicians able to understand and use complex global data. At the height of the *Mission to Planet Earth* program, approximately two terabytes of data per day will be generated. This staggering amount of data needs to be analyzed and assimilated to be of value. Students need training now to be able to understand and use this information in the future. An important goal of the *GeoCam* mission is to provide hands-on experience for students in visualizing and interpreting global environmental change. This training will better prepare them to make informed decisions that will determine the quality of life on the battered world that they will inherit.



G324 Payload Integration Can Do Photo

TECHNICAL DESCRIPTION

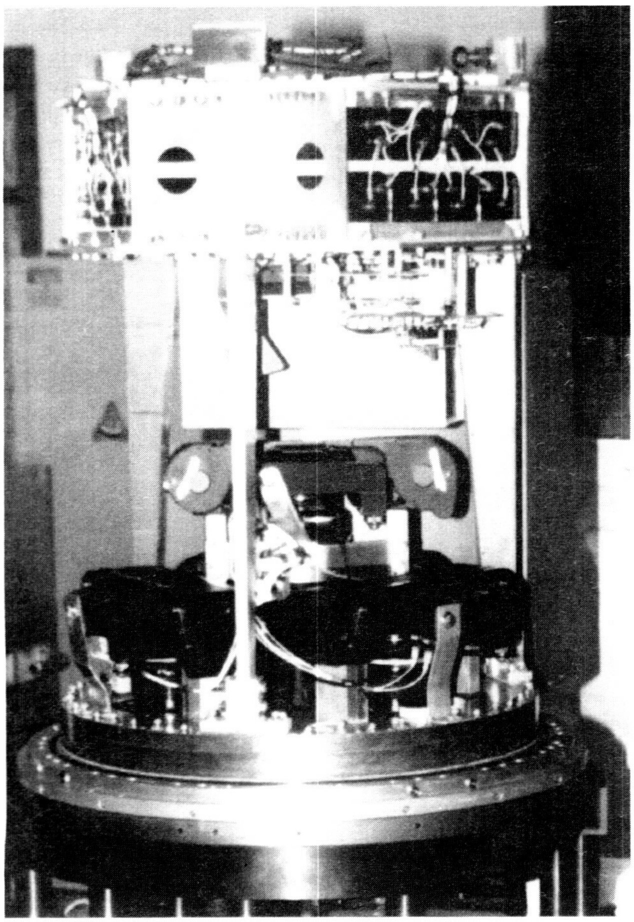
G-324 flew as a five cubic foot payload contained behind a Standardized Door Assembly (SDA) fitted with a 0.92 inch by 19.25 inch fused silica window. An internal 0.625 inch aluminum faceplate, which supports four Nikon F3 cameras fitted with 250 exposure film backs, also provides impact isolation for the window as an integral part of the payload fracture control plan. This plan calls for the isolation of the window from debris weighing 0.25 pounds or more, a size that could conceivably scratch it. A nick or microscopic scratch on the window could propagate to catastrophic proportions, making this a failure point in the structure. A sealed five cubic foot flight canister itself is considered containment for a loose 200 pound object.



S.D.A. Opening NASA TV

During ascent, a barometric pressure relief valve lowers the internal nitrogen pressure to 7.5 psia in an effort to further reduce the stress on the window. At payload activation - or during operation, a differential pressure switch monitors the internal pressure of the payload. If the internal pressure approaches the cargo bay pressure, there is a seal failure, and it must be assumed that there is a failure of the window. Upon detecting a failure, the differential pressure switch will inhibit SDA operation to protect the cargo bay and vehicle from debris damage. The SDA is further protected with an interlock from payload power which is controlled by GCD-A from several banks of 12-volt alkaline batteries.

In addition to the 1000 picture capacity of the cameras in the primary experiment, the G-324 flight contained 261 individual passive experiments, each in a 5.0ml cryogenic containment vial. The passive vials were further contained in an 11.5 x 7.5 x 4.5 inch aluminum box bolted to an internal structural plate. This method of containment, coupled with preselection guidelines, stringent materials examination, and full documentation, greatly simplified the safety procedures.



Can Do Photo

THE PAYLOAD POST FLIGHT

Post flight inspection of the payload was carried out in two stages. A general inspection of the payload and canister was carried out during deintegration of the payload at the Cape, and a detailed examination was performed after returning to Charleston. The film magazines were quickly examined for mechanical failure as the canister was lifted off, and found to be intact with expended film. G-324 WORKED!

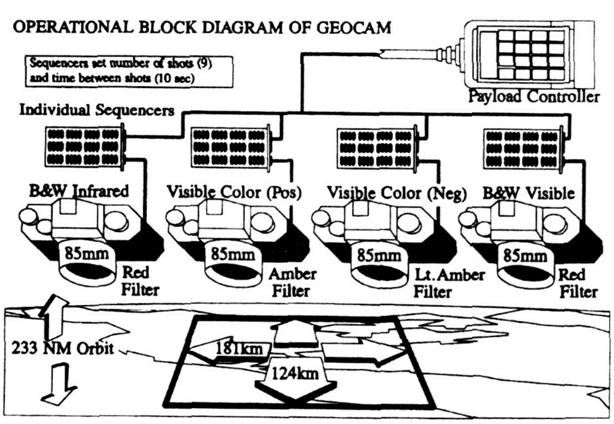
As the canister cleared the base (SDA deintegration takes place upside-down with the door in its jig), the rest of the payload appeared intact. At this point, loaded voltage readings were recorded on all batteries, and found to be well within the expected range. The environmental system was higher than expected, indicating minimal drain by the heaters, thanks in part to the earth viewing mission. All four cameras indicated a full mission profile run by the film counters, but two showed inconsistent values. Later examination showed the counters probably shifted due to vibration, since the film was expended. The payload was separated from the SDA by removing the 10-32 mounting ring bolts, and the payload was lifted free. An examination of the payload face and light baffles showed the flat black paint remained firmly bonded to all surfaces, the light baffles were intact, the baffle to lens seals were intact and all lenses were firmly locked to their respective cameras. An examination of the SDA window showed no visible scratches or damage to the interior window surface. Upon closer inspection of the SDA window, a slight greasy and somewhat crystalline blur about three inches in diameter was noticed in the center of the window. At the center of this blur was a slight buildup, translucent light brown in color, that resembled a slight bump or beginning of a drip. During the integration procedure, the window was meticulously cleaned and inspected by the GSFC integration crew and inspected and passed for assembly by both the G-324 PI and Chief Engineer. During the final test of the payload after integration, the door was opened and the cameras cycled for one complete nine exposure photo series. At that time, the window was again checked for contamination, and none was found. The spot had the appearance of a condensation deposit that resembled the Apiezon grease used on the sealing O-ring. A sample wipe was taken for later analysis by the integration crew.

All cameras performed as expected, yielding outstanding photographs, with the exception of the center camera. Although a few photographs are relatively clear from this camera, analysis shows the blur was there from the beginning. The deposit is dynamic in nature, changing its brown translucent density during the 125 orbit mission. GSFC will make further tests to determine the origin and mechanism of the deposit and determine the procedures necessary to prevent its recurrence on future flights of the window.

CAMERA SYSTEM

The GeoCam camera system consisted of four 35mm single lens reflex cameras equipped with 250 exposure film backs. The lenses were chosen to specifically match the STS-57 planned altitude of 230 nm. With a 85 mm focal length lens, each photograph encompassed an area of approximately 180 km by 125 km (22,400 km^2). This compares with 26,500 km^2 for the Skylab S190A multispectral camera system which GeoCam was designed to emulate.

The camera system lacked any positive motion compensation to prevent image blur so shutter speeds were selected to prevent motion degradation of the images. Using the orbital speed of 7.66 km/sec and calculating the limits of motion to prevent visible blurring, it was determined that a minimum shutter speed of 1/500th was required. By using 85 mm lenses with a maximum aperture of *f*1.4, this exposure was achieved while still permitting the use of high resolution slow speed films. The lenses were set at or near the maximum aperture of *f*1.4 because the Earth was always at infinity focus and depth of focus was not a consideration. This required careful prefocusing on an optical bench and positive securing of the focus mechanism to prevent slippage due to vibration.



FILM AND FILTER SELECTION

To compensate for the relatively small 35 mm film size, the films selected were the finest grain, highest resolution available. The Skylab S190A camera system used four types of film; black-and-white visible, black-and-white infrared, color infrared and color visible. It was determined that the infrared color film would significantly deteriorate during the relatively long GAS payload storage period, so it was reluctantly omitted from G324. An extra roll of color negative film was flown as a back up to the color transparency film instead. This turned out to be a fortunate choice.

All of the cameras were equipped with filters either to limit spectral range or to correct image quality. In all cases, the filter was used to eliminate the ultraviolet which is the wavelength most scattered by particulates and pollutants in the atmosphere.

FILM TYPE	FILM SPEED (iso)	FILTER TYPE	FILTER COLOR	WAVE-LENGTH (μm)
B&W Infrared	50	25	Red	0.7-0.9
Color (Slide)	64	85B	Amber	0.5-0.7
Color (Print)	25	81C	Light Amber	0.5-0.7
B&W Visible	25	21	Orange	0.6-0.7

OPERATIONAL CAMERA CONTROL

The shuttle crew initiated each camera activation. Each camera was controlled by an individual sequencer to control the number of individual shots for each activation and to set the interval between photographs. The interval was determined by the coverage of the lenses and the orbiter's speed over ground. On STS-57, a 10 second interval between shots provided an image overlap of 15 - 50% depending on the orientation of the rectangular film format to the direction of the orbiter's forward motion. Each photo sequence consisted of nine shots on each camera.

Exposure was controlled by the cameras standard automatic exposure meter. The film speed was determined by careful ground testing using actual lenses and filters and controlled lighting simulating in-flight conditions. This resulted in usable exposures on all shots with only minor variations caused by such artifacts as bright clouds in the center of the active meter. In no case were these variations beyond range of printing correction.

THE CAN DO GeoCam CONTROL ROOM

To allow students to directly participate in the flight and to have active input in the Earth photography, a unique control room was set up at the Medical University of South Carolina. The functions were divided into four desks each operated by a team of four students with a teacher advisor.

Student Control Room NGS Photo

OPERATIONS

Students at the operations desk monitored crew activities by using the mission timeline. They updated the timeline as required by monitoring NASA Select Television and Shuttle radio transmissions. It was their responsibility to know when orbiter orientation and crew activities permitted use of the camera system.

WEATHER

The weather desk staff monitored worldwide weather patterns to look for cloud conditions that would allow successful photography. They relied on satellite weather images relayed by the Earth Observation Lab at Johnson Space Center. Additional information was supplied by a student team working at the Charleston Air Force Base weather office. The students forecast weather and cloud conditions one day ahead since each day's target selections were made for the next day's execute package.

TARGETING

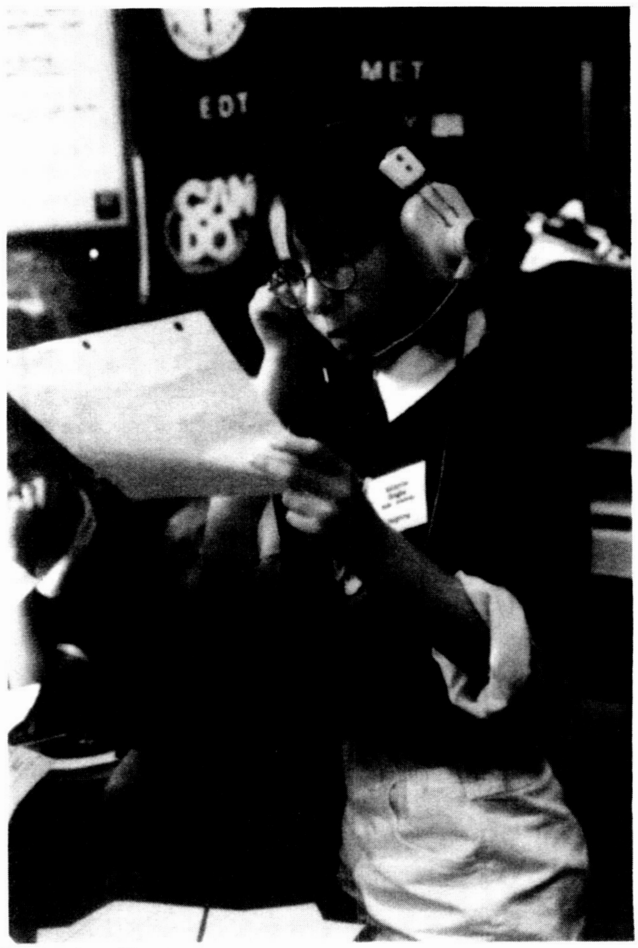
The students at the targeting desk correlated the daily orbital path of the shuttle with potential targets of geological or environmental interest. Targeters had to have a thorough knowledge of geography, geology and maps. Candidate targets were checked through the weather and operations desks to determine if photographic coverage was possible.

COMMUNICATION

The communications staff worked with targeting and operations to prepare the target list for the Johnson Space Center to uplink to the shuttle. They prepared daily updates on the flight for press and student briefing. This desk was also responsible for handling all public relations activities.

CONTROL ROOM EDUCATIONAL BENEFITS

Far more than the production of the daily target list, the main value of the control room was as an educational tool of immense power. The opportunity to operate in a meaningful decision making position proved to be a powerful motivation for learning. Students learned geography, orbital physics, shuttle activities and many other disciplines. Often this learning was done on their personal initiative based on a desire to maximize this once in a lifetime experience. Knowing that this was no simulation, but rather an actual functioning payload operations control room produced a very high level of interest and excitement. A senior editor from the National Geographic Society, use to student geographic ignorance, was amazed at the level of knowledge achieved by the targeting teams. A newspaper reporter was startled when a first grade student explained how to tell infrared from visible light satellite images. His class spent several Saturdays at the Air Force Base Weather Office learning these skills.



Targeting Desk NGS Photo

STS-57 CREW INPUT

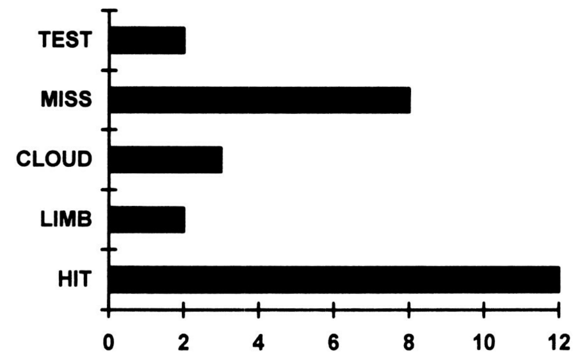
In addition to their commitment to execute the student list as much as possible, the crew obtained permission to freely activate the cameras on their own initiative. This fostered a true feeling of team effort with the students. The crew was also in a position to take targets of opportunity that might not have been included in the execute package. The value of this teamwork was illustrated by the superb and extremely rare photo sequence of the Congo basin. The Congo is almost always blanketed in clouds and nothing in the weather satellite images indicated a change. Consequently, it was never listed as a potential target. The alert crew, however, spotted an opening in time to fire the cameras. The result was unique enough to rate a fold-out display in the August 1994 *National Geographic Magazine*.

Astronaut Nancy Sherlock uses the A.P.C. NASA

PHOTO LOG

All photo sequences activated by the STS-57 crew resulted in a full nine shot sequence on all four cameras. All cameras performed faultlessly until all available film was exposed. Not all activations resulted in successful photos of the ground however. The largest group of misses(30% of all shots) were a result of the flight crew receiving inaccurate information from the ground concerning the angle of view of the camera system. This resulted in eight photo runs missing the Earth entirely. Aside from this mishap, the percentage of useful sequences on the remaining film was an outstanding 82%. The two runs showing the limb of the Earth proved both useful and popular although not originally planned.

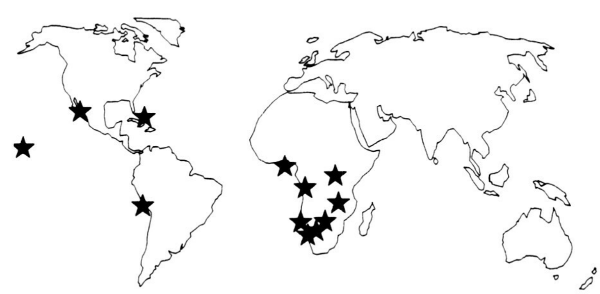
RESULT OF 27 RUNS



LIST OF GROUND TARGETS

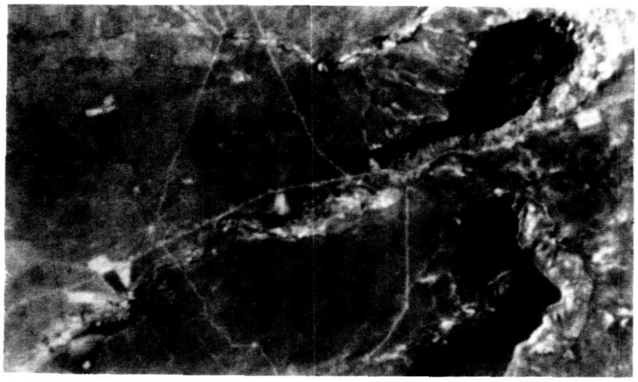
A list of the successful ground targets in the order in which they were taken:

1. Bahamas Islands
2. Skeleton Coast of Namibia (Africa)
3. Kalahari Desert (Africa)
4. Baja (Mexico)
5. Great Sand Sea of Namibia (Africa)
6. Hawaiian Islands
7. Atacam Desert of Chile (South America)
8. Chari River (Africa)
9. Lakes Albert and Kyoga (Africa)
10. Cape Verde on Senegal Coast (Africa)
11. Congo (Zaire) River Basin (Africa)
12. Katanga Plateau (Africa)



SKYLAB TARGETS

One goal announced in the 1992 Symposium Proceedings was the attempt to rephotograph areas documented by the SkyLab S190A camera system. Technically, the GeoCam camera system did a good jog of emulating the S190A. Unfortunately, in large part due to the time of launch, no matching areas were photographed.



Extreme Enlargement From a Photo of the Kalahari Desert to Show Clearly Resolved Roads and Trails.
GeoCam Photo

PHOTOGRAPHIC RESULTS

Focus was consistently excellent validating the value of optical bench calibration. Enlargement of the negatives established that the 500th of a second exposure eliminated any evidence of image streaking from motion. The photographic experts at Johnson Space Center advised us not to expect resolution better than 30 meters at this image scale. This figure was based on results obtained with hand held cameras through the orbiter's multilayered safety windows. In fact, under ideal visibility conditions, resolutions under 10 meters were obtained. In the photos of the Kalahari Desert, individual trails and one lane roads were clearly resolved. In the dry air of the Atacam Desert, individual mining buildings and sheds are clearly seen. This extraordinary image quality was apparently the result of superb lenses, optical bench prefocusing, a top quality optical window and ultrafine grain film. On a later shuttle flight, the crew attempted to use the same black-and-white film. Because of the need to use a smaller aperture to compensate for manual focusing, the pictures were unsuccessful due to excessive motion .

PUBLICATION AND DISPLAY

. **Smithsonian Institution Air and Space Museum**

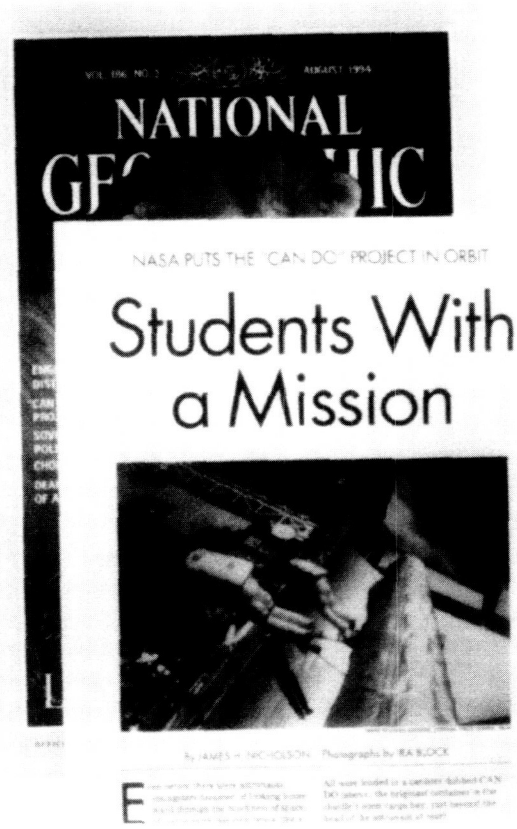
A black and white print of the Atacam Desert was selected for display in the "Looking at Earth Gallery" of the Air and Space Museum from Sept. 1994 to Sept. 1995. This museum is the most popular in the world with visitors.

South Carolina State Museum

The state museum in Columbia, South Carolina built a complete exhibit on the CAN DO Project. the exhibit includes color and black and white prints as well as a continuous video illustrating control room activities. Originally scheduled for one year, the display has been extended for another six months.

National Geographic Magazine

A long time supporter of the project, the National Geographic Society became interested in an article as the flight became a reality. The result was a sixteen page article in the August 1994 issue. The article which covered the whole CAN DO Project, featured a centerfold with photographs of the Congo River and the Skeleton Coast of Namibia.



National Geographic *WORLD* Magazine

As a companion to the article in the adult magazine, the National Geographic Society published an article in WORLD, their student publication. It also was published in August, 1994 and featured a photo of the shuttle above the Baja,

***OWL* Magazine**

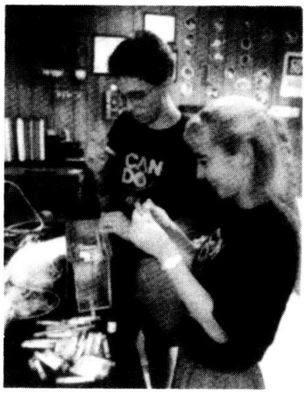
OWL is a popular Canadian Children's magazine. It covered the CAN DO Project in a February 1995 article titled "Kids With a Mission". The article also covered some other student space activities.

***SHUTTERBUG* Magazine**

A photography magazine, *Shutterbug*, published an article in November 1994 titled "Space Photography - An Educational Experience". Written by freelance author Philip Chen, the article discussed the photographic design of the payload.

EXPERIMENT MAGAZINE

In July of 1995, the Greek Magazine *Experiment* carried a 14 page article. The magazine is similar to National Geographic and carried a slightly modified version of the NGS article in Greek.



Η ΕΠΙΣΤΡΟΦΗ ΤΗΣ ΑΠΟΣΤΟΛΗΣ

Στο Διαστημικό Κέντρο Κένεντυ, ο μηχανικός Τομ Ο'Μπράιεν κι ο συγγραφέας αυτού του άρθρου (απέναντι αριστερά) ανοίγουν τη σκευοθήκη της αποστολής CAN DO αμέσως μετά την επιστροφή της.
Η βοηθός της αποστολής Σάμερ Σπάρκμαν και ο μαθητής λυκείου Έιντριαν Νάιντα (αριστερά) επεξεργάζονται τους δοκιμαστικούς σωλήνες που έστειλαν οι μαθητές στο διάστημα.
Η πεντακάθαρη φωτογραφία της Ακτής των Σκελετών (κάτω), στη νοτιοδυτική Αφρική, δείχνει τόσο πολλές λεπτομέρειες, που θα δώσει στοιχεία για πολλές γεωλογικές και γεωγραφικές μελέτες τα επόμενα χρόνια.

It's Greek to Us NGS/Experiment Photo

South Carolina Educational Television

The entire project was superbly recorded in an hour long television documentary produced and regionally broadcast by South Carolina Educational Television. Television crews filmed every step of the payload construction and integration process. In addition, in-flight footage was provided through the courtesy of the television facilities at Johnson Space Center.

POST FLIGHT EDUCATIONAL ACTIVITIES

Having obtained outstanding photographs of the Earth, the next step is to develop new and innovative ways to use them in the classroom. It has been discovered that excellent results are obtained through the use of very large prints which the students can examine in detail. Laminated !6 x 20 inch enlargements of the black and white photos have been produced for classroom use. The particular use depends on the grade level and interest of the class. One example is the use of the Atacam Desert photos to illustrate volcanism and mountain building. The run includes, dry lakes, new volcanoes and the edge of the Andes Mountains. The Katanga Plateau sequence has three major lakes all of which show obvious signs of loss of water level in recent years. They illustrate all too well the desertification afflicting so much of Africa. Photos can also be used in conjunction with other educational materials. The striking photo of the Skeleton Coast of Namibia shows many of the features described in the National Geographic television feature and magazine article on this desolate spot. Individual teachers develop curriculum based materials in their particular areas of interest which are then shared with other teachers.

GROUND TRUTHING

In July 1995, 28 Charleston County Teachers sailed to the Bahamas as part of a special course in Tropical Marine Science. They were able to sail across and dive on some of the reefs shown in the beautiful photos taken of the Berry Islands. This unique ground truthing experience helped the teachers see close up the information contained in the GeoCam photos.

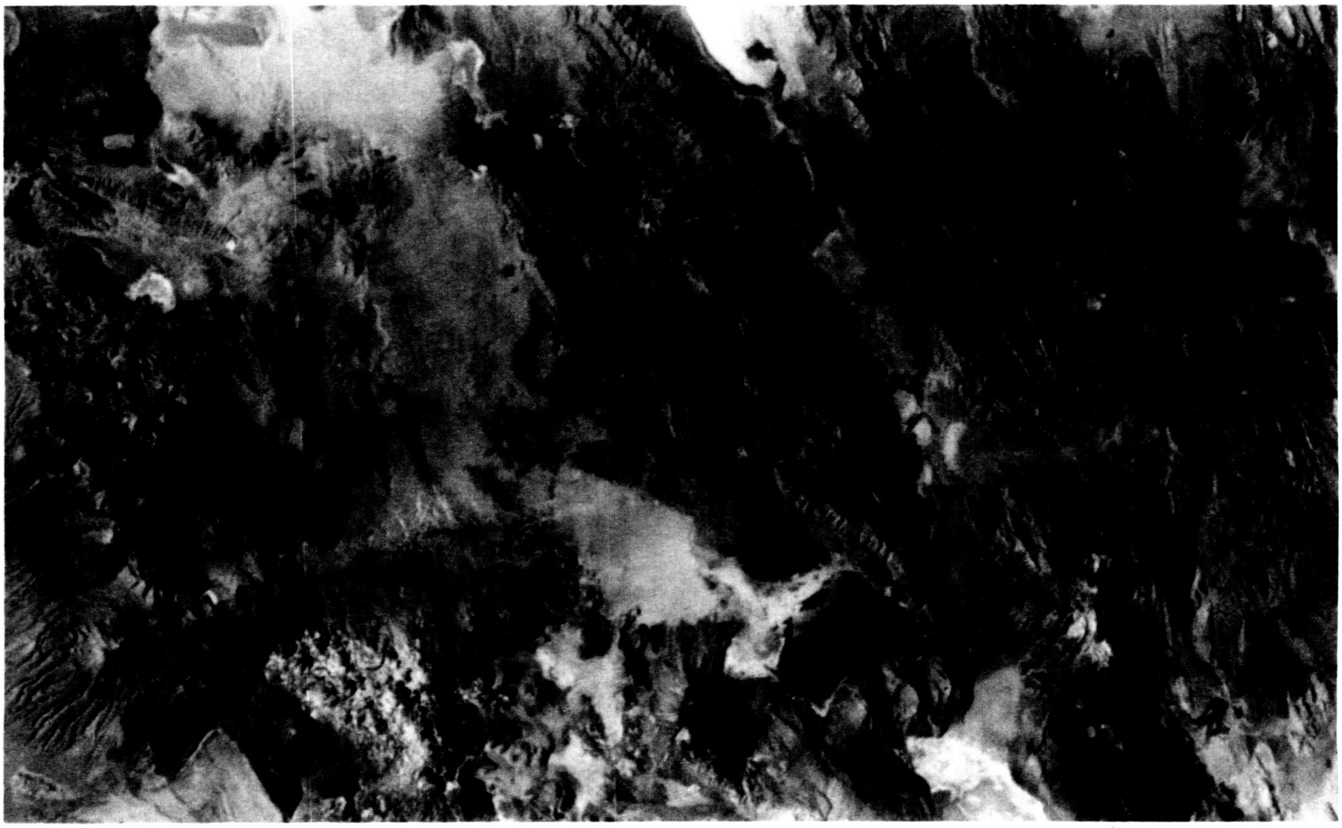
Teachers "Ground" Truth the Bahamas by Sailboat
Can Do Photo

FUTURE GOALS

The Can Do Project has a wide ranging program of activities underway. Last July, the program sent teachers to both Australia and the Hubble Space Telescope Institute in Baltimore. From these locations, the teachers were eye witnesses to the spectacular impact of Comet Shoemaker Levy 9 with Jupiter. The Australian team flew eight miles up into the stratosphere aboard the NASA Kuiper Airborne Observatory.

The program continues to enjoy the active support of the South Carolina Space Grant. This has produced a very productive working partnership. Can Do is also actively participating in the KidSat Program with J.P.L.

One dream that is very much alive is to fly GeoCam again. Using the lessons learned and the experiences gained, the Can Do team believes that it could be even better than the first time. Two innovations planned would be the use of digital cameras and an Internet Home Page to put the control room in touch with students everywhere. The flight of STS-57 completed part of the CAN DO goals, but it also represents one part of a work still in progress.



GeoCam Photograph of the Atacam Desert of Chile GeoCam Photo