# EARTH OBSERVATION PHOTOGRAPHY

## LOOKING BACK 20 YEARS AFTER SKYLAB

**GAS #324 CHARLESTON COUNTY SCHOOL DISTRICT CAN DO PROJECT**

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| *James H. Nicholson* | *Principal Investigator* | *Medical University of South Carolina* |
| *Thomas J. O'Brien* | *Chief Engineer* | *Medical University of South Carolina* |
| *Mitchell Colgan* | *Geology Science Advisor* | *College of Charleston* |
| *Ruth Ashcraft-Truluck* | *Steering Committee* | *Wando High School* |
| *James R. Frysinger* | *Orbital Physics* | *Academic Magnet High School* |
| *Carol A. Tempel* | *Coordinator* | *Charleston County School District* |


## ABSTRACT

The Charleston County School District **CAN DO** project (GAS #324) was designed originally to photograph the 1986 apparition of Comet Halley. Postponed because of the Challenger disaster of that year, the project had to select new goals. Wishing to retain the already tested design, it was decided to turn the cameras towards the home planet instead. Because the various disciplines of earth science appear in curricula at many different grade levels, it was realized that high quality photographs of the Earth would have tremendous educational potential. A steering committee of trained classroom teachers, backed by a volunteer team of technical experts and academic advisors has developed a program for earth science based on photographs obtained from low earth orbit.

In selecting targeting objectives, immediate note was made of the fact nearly one generation (20 years) has passed since the United States' ambitious SKYLAB program was conducted. A critical part of those missions was the acquisition of earth photography using a six camera, multi-spectral camera system. This objective was systematically furthered through the term of three separate crew visits to the Space Station in 1973-74. Not merely an exercise in randomly photographing the Earth below, the purpose of the Earth Resource Experiment Package (EREP) was to determine what kind, and how much, photographic data could be acquired of the broad variety of Earth features witnessed on the mission's ground track. This activity was underwritten by intensive training before lift-off, real-time scientific mission planning and on-board procedural support ... qualities which have corollaries to what is here proposed.

The collection of 35,000 photos produced by EREP, in six registered wavelengths, represents still the most complete photographic coverage of the planet undertaken. Even as such, though, the body of data remains under-utilized. GAS #324 intends to operationally re-visit in part what is a considerable national asset, and to contribute an added tier of relevancy to this remarkable inventory of planetary data. Improvements in modern film technology will allow the G324 camera system to match closely the larger SKYLAB film format in both coverage and quality. The photography acquired by CAN DO should allow a direct examination and comparison of the changes that have occurred to the Globe in the last twenty years.

## INTRODUCTION

## THE IMPORTANCE OF EARTH OBSERVATION PHOTOGRAPHY

Later this decade, earth sensing platforms will analyze earth processes as part of a multi-national program, "Mission to Planet Earth". A rationale for the Mission comes from planetary exploration that affirms our world's special place. The Earth is the only known planet with a biosphere, abundant oxygen, liquid water, and surface renewing tectonic activity. Biogeochemical functions recycle nutrients, water, and gases that are essential to life. The Mission is concerned with changes that are occurring in such areas as atmospheric chemistry, biomass distribution, primary productivity, and population growth. By examining the past and monitoring the present, it is hoped to reach a deeper understanding of the evolution of the Earth on all time-scales. Because of the role humans now play in shaping local and global environments, a goal of this Mission is to document natural and human induced changes on the Earth over the next twenty years. Policy makers and scientists alike view the next twenty years as critical.

In twenty years the global population level will reach more than 6 billion. In less than forty years, from 1950 to 1988, world population doubled from 2.5 to 5 billion. By the year 2025, the United Nation projects population levels to reach 8.5 billion. A population growing at this rate places strong pressures on many of the earth's systems and accelerates the rate of global, as well as, local change. For example deforestation occurs at an estimated rate of 11.3 million hectares annually, industrialization pumps an additional 5,000 TgC (gigatons of carbon) of $CO_2$ into the atmosphere each year, and 20 to 25% of the existing tropical species are projected to undergo extinction.

Historical examinations of change often look far back into Earth's history to determine the rate and degree of natural changes. The rapid growth of human population presents fundamentally different pressures on the Earth's ecosystem. To gain new insight on human-induced changes, earth scientists focus on the changes that occurred over a shorter time span (20 years). During this time, natural and human induced changes on the surface of the earth have been photographed from space. Comparison between photos, past and present (especially, time series photography), enables documentation of the profound changes to the Earth. One of the largest data sets of earth observing photographs comes from the SKYLAB archives. These photographs covered most of the Earth's surface, and provide an important baseline to compare present and future photographs of the Earth taken from orbit. It is a major goal of the CAN DO project to provide a direct link to this resource.

## THE VIEW FROM SPACE

Photographic analyses of land use practices give insight into changes. Linear functions can be used to project the rate of future change. As growing human population requires an ever increasing share of the Earth's surface on which to live, human activities change the distribution of plants and animals, alter drainage patterns, and modify natural boundaries. In doing so, mankind changes either the reflective or emissive properties of the surface. Such changes are detectable from space. Human actions that change the reflectance or color of the Earth's surface can be recorded with space photography. Activities include:

**DEFORESTATION.** Forests are optically dense, green areas. The cutting of the trees produces a more reflective surface and exposes a different color. Deforestation scars are seen in the rain forests throughout the world. Forests are often cleared by setting fire to the vegetation, and smoke from these fires is visible from space.

**URBANIZATION.** Urban areas are delineated by highly reflective paved surfaces. Because the growth of cities is at the expense of vegetated surfaces, the increase in reflectivity can be measured.

***FIGURE 1 SKYLAB 1973***

**RIVER SEDIMENT LOADS.** Clear cut forestry practices in many tropical countries have altered the sedimentary load of the rivers that drain the forest. Rivers loaded with sediment have a different color than "clean" rivers that drain forested areas. Sediment laden rivers, such as the Betsiboka River of Madagascar, are now red-brown when seen from space.

**DESERTIFICATION.** The reflective surface of deserts and eolian sediment patterns are also visible from space. The encroachment of deserts over once vegetated surfaces will register a shift in the optical and textural character.

**COASTAL EROSION.** Analysis of the position of the coastal features can be used to determine the rate and location of large scale coastal changes. Dramatic rates of erosion can be seen on the edge of the Nile and Ganges river deltas.

**LAKE LEVELS.** Changes in boundary relations can detect variation in water levels in lakes (e. g., Lake Chad) or inland seas (e.g., Aral Sea).

**WETLANDS.** The delineation of wetlands is sometimes difficult. Changes in vegetation color and the sea land boundary are sometimes needed to detect loss.

## EARTH OBSERVATION AND EDUCATION

Photographic comparisons are powerful teaching tools. Their utility is particularly pronounced as regards change over time. By comparing transformation that has been documented in earth viewing photographs, changes that have occurred in our lifetimes can be observed. It is hoped that such documentation of global change will make this issue more immediate and real. There is a collateral benefit that will accrue in addition.

NASA and other federal agencies are concerned about the projected shortage of scientists and technicians able to use and understand global data sets. 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 CAN DO G324 mission is to provide a vehicle for stimulating hands-on experiences for students so that they can better interpret the global environmental changes that will determine the quality of the world that they will inherit.

## THE VIEW FROM THE CLASSROOM

There has been a national movement in science education in recent years that recognizes and promotes the importance of utilizing modeling to teach process skills. These skills are used by earth scientists and may be used by intelligent informed citizens as well. Unfortunately, many students graduate from high school without an adequate foundation in this area. There is a clear need for better integration of the necessary process skills at all levels of curriculum.

The CAN DO pictures can be used as a springboard for this purpose. Students can use the photographs to make observations about land formations, weather activity, and the effect of man's presence on the planet. The destructive burning of forest land and the production of visible pollution make particularly graphic examples. Students can make inferences about these observations and model predictions of future changes that will result. Comparisons to matched SKYLAB photographs taken two decades ago will allow students to quantify the amount of change. The infrared pictures will document features not seen from the ground, such as changes in vegetation, when compared to earlier pictures. Night time shots can be dramatic for students by showing the concentration of city illumination as a measure of population density and energy usage. Such photographs can open a dialogue on world population and the problems that result, generating such questions as : what is happening to our farmlands; how much food will it take to feed the world's population; what are the problems of food distribution; and why do they occur? Students may be inspired to research the literature, communicate their findings, and even design experiments to answer their questions.

In addition, G324 is designed to contain 250 small passive student experiments. These individual experiments allow students at all grade levels to participate directly in space research. What better way to involve students in our national space program at an early age. The best learning takes place when the learner experiences hands-on involvement.

## PAYLOAD DESIGN

The CAN DO payload utilizes GAS hardware and is housed in a 5.0 cubic foot canister equipped with a standard door assembly (SDA). The canister is sealed with a .92 inch fused silica window, which is optically flat and ground to a quarter wave tolerance. The fused silica window characteristics will permit photography in visible light, infrared and ultraviolet wavelengths. At the start of the mission, the motorized door will be opened, and will not close until its completion. In the event of premature battery failure, or loss of pressurization, the door closes automatically. Since the batteries are more cold sensitive than the cameras, the continued open condition of the door indicates sufficient battery power and survivable conditions in the canister.

The structure is a three strut design with a heavy structural face plate at the top, and battery compartments at the base. The cameras are hung from the face plate on struts of a length required for the lenses in use. The control electronics, heaters, and fans are mounted above the battery compartment. All structural components are fabricated of 6061-T6 aluminum and have been tested both by a detailed structural analysis and actual three axis shake and vibration testing at Langley Research Center.

All power is supplied by industrial alkaline batteries which have been thoroughly tested for cold tolerance, safety, and leakage. Because of the extremely low level of hydrogen gas generation, the alkaline batteries do not require venting. The battery stacks have been designed for redundancy and include both diode and fuse protection. Battery capacity is allotted to provide adequate power for camera operation and environmental control for a mission duration in excess of ten days. Supplemental heat and atmospheric circulation (to compensate for lack of convection) is provided by redundant mil-spec fans and strip heaters. The environmental system is designed to maintain a 0° C temperature based on experience operating the same cameras on board a stratospheric research aircraft. The electronic systems were tested for EMI at Goddard SFC and found to be interference free.

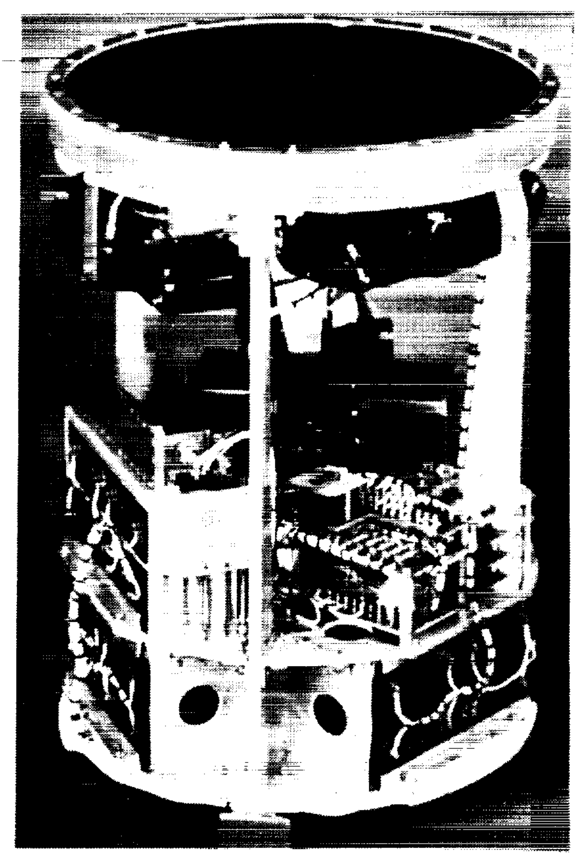


*FIGURE 2 G324 PAYLOAD*

## PHOTOGRAPHIC DESIGN

The primary goal for the design of the optical and photographic systems is to match as closely as possible the results of the SKYLAB S190A and S190B camera systems. This includes the selection of focal lengths to match the photographic "footprint" of the cameras as well as the use of modern fine grain, high resolution films to compensate for the difference in camera format.

The SKYLAB spacecraft was launched on May 14, 1973 into a nearly circular orbit at an altitude of 435 km above the Earth. The launch azimuth inclined the orbital plane 50° with respect to the Equator and allowed observations of the Earth between latitudes 50°N and 50°S. It orbited the Earth every 93 minutes and repeated the ground track every 5 days. The photographic return from the Earth Resources Experiment Package (EREP) was as follows:

| MISSION | DATES | DAYS | PASSES | TOTAL PHOTOS |
|---|---|---|---|---|
| Skylab2 | 5/25/73-6/22/73 | 28 | 13 | 5,275 |
| Skylab3 | 7/28/73-9/25/73 | 59 | 48 | 13,429 |
| Skylab4 | 11/16/73-2/8/74 | 84 | 49 | 17,000 |
| TOTAL | | **171** | **110** | **35,704** |


*FIGURE 3 SKYLAB S190A CAMERA SYSTEM*

## SKYLAB CAMERA SYSTEMS

### S190A Multispectral Photographic Camera System

The S190A system consisted of six bore-sighted 70mm cameras equipped with 152mm focal length lenses. Each photograph covered a square image area of 163 km on a side. Each camera was equipped with filters to cover a specific wavelength on a combination of color, black-and-white, color infrared and black-and-white infrared film. The cameras were mounted in a frame that provided programmable camera rotation to compensate for the forward motion of the spacecraft.

### S190B Earth Terrain Camera

The S190B was a single 127mm camera equipped with a 457mm lens. Each photograph covered an area of 109 km square. Film could be selected from a choice of color, black-and-white or color infrared emulsions with an appropriate filter. An internal motion compensator corrected for the forward motion of the space craft.

## G324 CAN DO CAMERA SYSTEM

The G324 payload is a candidate for the flight of STS-57, currently scheduled for launch in late April of 1993. STS-57 will be at a mean orbital altitude of 431.5 km with an inclination of 28.45°. During the scheduled seven day mission, approximately 46 of the planned 108 orbits are -Z axis pointing (cargo bay towards earth).

The G324 camera system consists of four 35mm single lens reflex cameras equipped with 250 exposure film backs. With an 85mm focal length lens, each photograph will encompass an area of 180.8 km by 123.9 km. The total ground area for each view will be 22,401 $km^2$ compared to 26,569 $km^2$ for the S190A multispectral system and 11,881 $km^2$ for the S190B terrain camera. The G324 film format is rectangular (24 x 36mm), while both Skylab film formats were square. The G324 camera system lacks any positive motion compensator to prevent image blur from motion over the ground, so that shutter speeds on the cameras must be selected to prevent motion degradation of the images. With an orbital speed of 7.66 km/sec (27,574 kph), an exposure of 1/250th of a second would allow 30 meters of motion. This approximates the best resolution possible at this image scale. General practice accepts motion blur as negligible when it approximates 1/2 of the image resolution; therefore, all cameras will be set to an exposure time of 1/500th of a second or shorter. By the use of 85mm lenses with a maximum aperture of f1.4, this exposure can be achieved while still permitting the use of slow speed, high resolution films. All lenses will be set at the maximum aperture of f1.4 because the subject is at infinity and depth of field is not a consideration. However, the shallow depth of focus will require careful prefocusing on an optical bench and positive securing of the focus mechanism to prevent slippage due to vibration.

| SYSTEM | FILM | LENS | ANGLE | IMAGE SIZE | TOTAL AREA |
|---|---|---|---|---|---|
| S190A | 70mm | 152mm | 21.2° | 163x163 km | 26,569 $km^2$ |
| S190B | 127mm | 457mm | 14.24° | 109x109 km | 11,881 $km^2$ |
| G324 | 35mm | 85mm | 28.5° | 124x181 km | 22,401 $km^2$ |

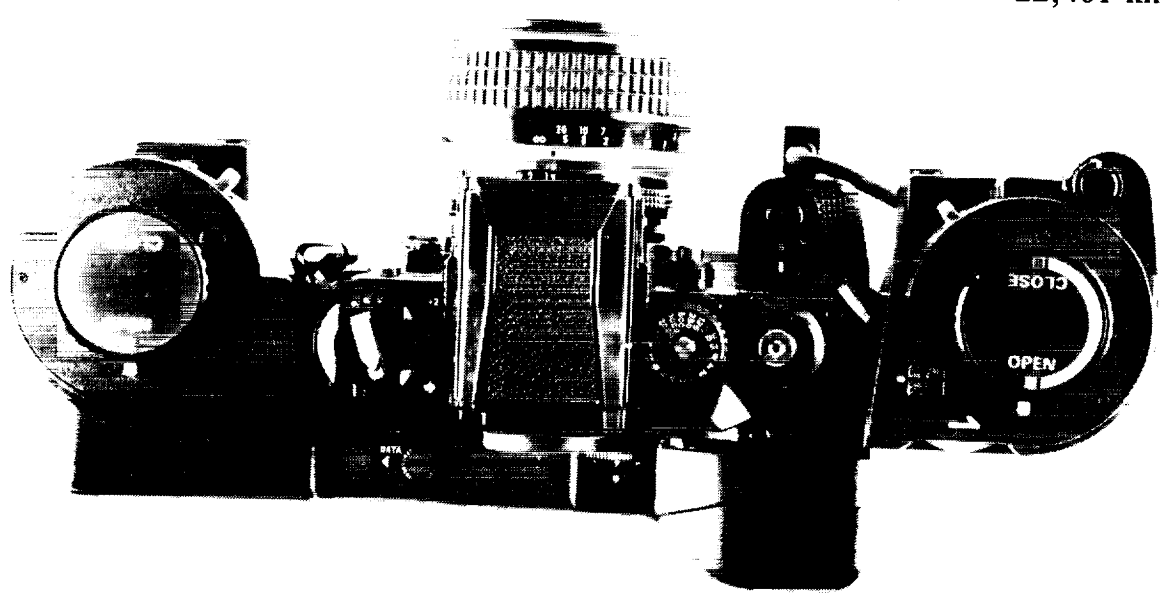



*FIGURE 4 CAMERA WITH 250 EXPOSURE BACK*

## FILM SELECTION

The Skylab S190A camera system used four types of films; black-and-white visible (Aerial PlusX), black-and white infrared, color infrared and color visible. All films were 70mm size. The G324 cameras will be using 35mm format, which has only 1/4 the image area. Much of this difference in resolution and graininess will be made up by the use of more modern films with improved grain structure and resolution. In addition, the G324 lenses have a maximum aperture of f1.4 which transmits four times more light than the S190A lenses' maximum aperture of f2.8. This greater light transmission will allow the use of slower (lower exposure index) films with inherently finer grain and higher resolution. For example G324 will use Technical Pan film with a film resolution of 325 lines/mm as compared to the S190A Aerial PlusX with a film resolution of 125 lines/mm. This gives the G324 cameras 62.9 lines of resolution per kilometer of ground coverage as opposed to 53.7 for the Skylab system. In the case of the infrared color and infrared black-and-white films, fewer improvements have been made. No suitable lower speed films are available, so that the film format difference can not be fully compensated.

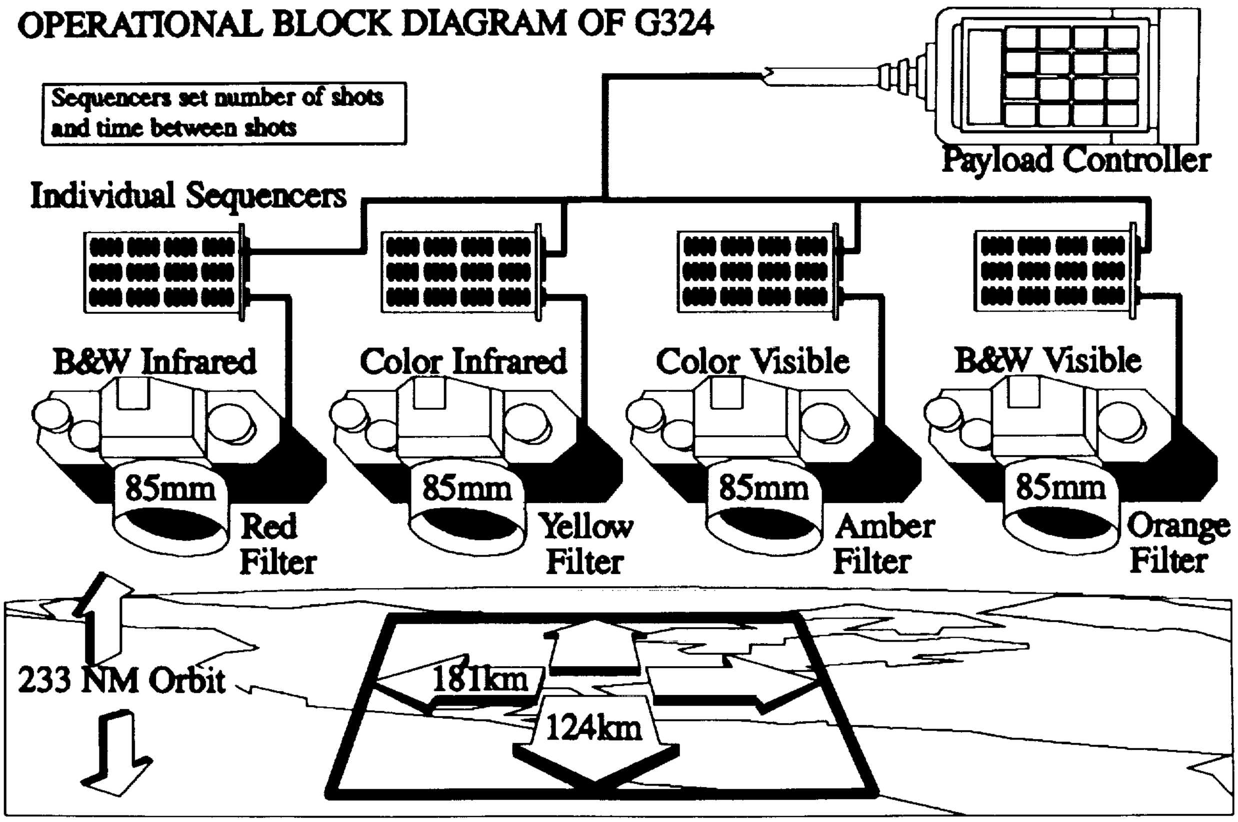
## FILTER SELECTION

All of the cameras will employ filters either to limit spectral range or to correct image quality. In all cases, the filter will be used to eliminate the ultraviolet, which is the wavelength most scattered by particulates and pollutants in the atmosphere. The greatest problem in the visible color photography is the excess blue caused by atmospheric scatter of short wavelength light. This blue haze can vary from almost none over mountains and desert areas to extremely high over temperate and subtropical forests and urban areas. To achieve maximum control of this effect, the camera will be equipped with a 85B (wratten) amber color correction filter. This will remove ultraviolet and most of the blue/violet. These wavelengths are most subject to atmospheric scatter. Where scatter is not prevalent, the excess yellow can be removed by correction in color printing.

| FILM | SPEED | FILTER | COLOR | WAVELENGTH (μm) |
|---|---|---|---|---|
| B&W Infrared | 50 | 25 | Red | 0.7-0.9 |
| Color Infrared | 25 | 12 | Yellow | 0.5-0.88 * |
| Color Visible | 25 | 85B | Amber | 0.5-0.7 * |
| B&W Visible | 25 | 21 | Orange | 0.6-0.7 |
| "NIGHT" | 6400 | -- | ----- | 0.4-0.7 * |

* films available in long rolls only by special order

OPERATIONAL BLOCK DIAGRAM OF G324




## OPERATIONAL CONTROL

Each camera is controlled by an individual sequencer to set the interval between photographs and to control the number of shots for each crew activation. The interval is determined by the coverage of the lenses and the orbiter's speed over ground. In the case of STS-57, a 15 second interval between shots would allow a spacing of 115 km, which would provide image overlap of 9% on the short (24mm) axis of the film and 52% on the long axis (36mm). The actual overlap for any camera will depend on the orientation of the camera body to the direction of the orbiter's forward motion.

Each camera has a total of 250 exposures available. The total number of photographs taken in each "photo run" will be primarily determined by the number of crew activations available.

| RUNS | #SHOTS | TIME | DISTANCE |
|---|---|---|---|
| 2 | 125 | 30m15s | 14,375km |
| 10 | 25 | 6m15s | 2,875km |
| 25 | 10 | 2m30s | 1,150km |

## FUTURE POTENTIAL

Because Earth observation has such wide reaching and enduring interest, especially in view of such long term programs as "Mission to Planet Earth", the Can Do team has been asked to consider the possibility of future use. After the flight of G324, the Charleston County School District has agreed to loan the payload and offer technical support to any suitable party that would use it for educational purposes. This use could take one of several possible forms.

### FUTURE GAS FLIGHTS

Some other school groups holding GAS reservation numbers have found it difficult to construct and test a qualified payload of their own. They might consider using the Can Do structure to obtain photographs of interest to their students as well as flying their own set of small passive student experiments.

### CAP PAYLOADS

The limited number of crew activations permissible under the GAS program restrict photography of specific targets of scientific interest. A CAP (Complex Autonomous Payload) secondary payload under the auspices of another NASA Earth investigation program would allow the more intensive crew involvement to perform the targeted and controlled photographic investigation necessary to support serious scientific research.

### HITCHHIKER

Under suitable sponsorship, it would be possible to expand the payload to a Hitchhiker status. This would allow the use of more cameras to cover other optical and wavelength options. In addition, the availability of a radio channel would permit realtime operation of the payload from the ground, eliminating the impact on crew time completely. A suitable control room for students could be set up complete with orbital tracking and satellite weather displays. Student teams would experience the real world of decision making in choosing lighting angles and weather conditions for the completion of their photographic missions.

## REFERENCES

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